

AD-A153 478

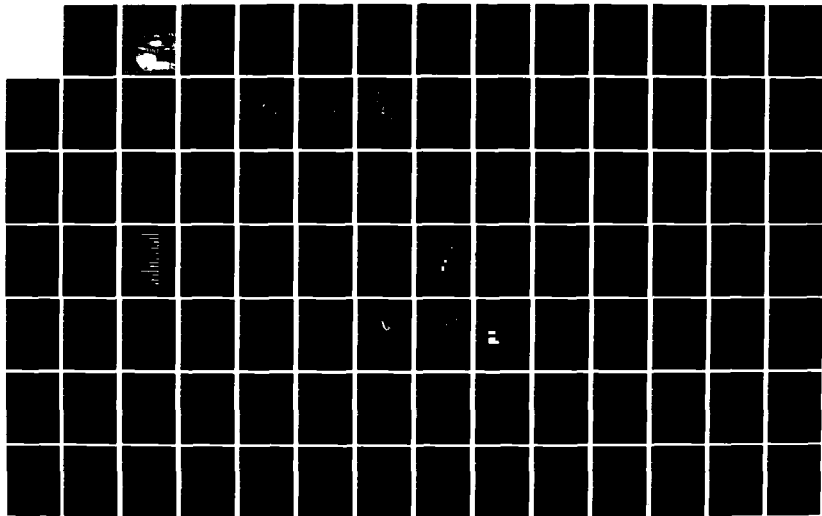
BENTHIC AND SEDIMENTOLOGICAL STUDIES OF THE GEORGETOWN  
OCEAN DREDGED MATE. (U) SOUTH CAROLINA WILDLIFE AND  
MARINE RESOURCES DEPT CHARLESTON M.  
R F VAN DOLAH ET AL. FEB 84 TR-59

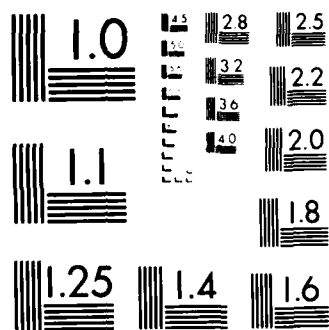
1/2

UNCLASSIFIED

F/G 8/10

NL





MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS 1963 A

AD-A153 478

North Carolina

CAPE HATTERAS

CAPE LOOKOUT

WILMINGTON

Carolina

# Benthic and Sedimentological Studies of the Wilmington Ocean Dredged Material Disposal Site

R.F. Van Dolah

CHARLESTON

SAVANNAH

Georgia

BRUNSWICK

JACKSONVILLE

Florida

ST AUGUSTINE

DAYTONA BEACH

DTIC

MAY 9 1985

Carolina Marine Resources Council  
Technical Report Number 59

February, 1984

Property of

This document has been approved  
for public release and sale; its  
distribution is unlimited.

85 04 10 001

Property of the  
U.S. Government

Return To:  
U.S. Army Corps of Engineers  
P.O. Box 21  
Fort Belvoir, MO 6402-0021  
Contract No. D-402-0919

Approved for Public Release: Distribution Unlimited.

Do not destroy this record when no longer

BENTHIC AND SEDIMENTOLOGICAL STUDIES OF THE  
GEORGETOWN OCEAN DREDGED MATERIAL  
DISPOSAL SITE<sup>1</sup>

by

Robert F. Van Dolah  
David M. Knott  
Elizabeth L. Wenner  
Thomas D. Mathews  
Michael P. Katuna<sup>2</sup>

Marine Resources Research Institute  
South Carolina Wildlife and Marine Resources Department  
P.O. Box 12559  
Charleston, South Carolina 29412

South Carolina Marine Resources Center  
Technical Report Number 59

FEBRUARY, 1984

<sup>1</sup>This study was funded under contract (#DACW60-83-C-0005) for the U.S. Army Corps of Engineers, Charleston District.

<sup>2</sup>Department of Geology, College of Charleston, Charleston, SC 29424.



## Table of Contents

	Page
LIST OF FIGURES .....	iii
LIST OF TABLES .....	iv
LIST OF APPENDICES .....	v
ACKNOWLEDGMENTS .....	1
INTRODUCTION .....	1
REVIEW OF EXISTING INFORMATION .....	1
ENVIRONMENTAL AND BIOLOGICAL CHARACTERISTICS .....	1
<u>Hydrography and Currents</u> .....	1
<u>Bottom Sediments</u> .....	3
<u>Chemistry and Pollutants</u> .....	3
<u>Biology</u> .....	7
LOCATION IN RELATION TO LIVING AND NON-LIVING RESOURCES .....	8
<u>Fisheries and Shellfish Grounds</u> .....	8
<u>Natural and Artificial Reefs</u> .....	12
<u>Endangered Species</u> .....	12
<u>Other Resources</u> .....	12
METHODS .....	12
LOCATION OF STUDY AREAS .....	12
HYDROGRAPHIC ASSESSMENT .....	14
SEDIMENTOLOGICAL ASSESSMENT .....	14
BENTHIC COMMUNITY ASSESSMENT .....	16
BIOACCUMULATION ASSESSMENT .....	17
RESULTS AND DISCUSSION .....	17
HYDROGRAPHY .....	17
<u>Oceanographic Parameters</u> .....	17
<u>Currents</u> .....	19
<u>Chemistry and Pollutants</u> .....	19
BOTTOM SEDIMENTS .....	19
<u>Granulometric Analyses</u> .....	19
<u>Chemistry and Pollutants</u> .....	30

	Page
BENTHIC COMMUNITIES .....	32
<u>Beam Trawl Collections</u> .....	32
<u>Grab Collections</u> .....	41
<u>Tissue Chemistry</u> .....	57
RECOMMENDATIONS AND SUGGESTED MONITORING PLAN .....	57
SUMMARY AND CONCLUSIONS .....	59
LITERATURE CITED .....	60
APPENDICES .....	64

## List of Figures

<u>Figure</u>	<u>Page</u>
1. Location of hydrographic study areas and surface circulation patterns .....	2
2. Landsat photograph of Winyah Bay and nearshore coastal waters .....	4
3. Areal distribution of mean grain size .....	5
4. Three-dimensional plot of bottom survey data collected in the Georgetown DMDS by the U.S. Army Corps of Engineers, April 1983 .....	6
5. Location of commercial and recreational fisheries resources .....	9
6. Location of endangered species and marine historical features .....	10
7. Location of preserves, wildlife centers, beaches and ports .....	11
8. Map showing location of the 15 possible sampling locations in the control and DMDS sites, as well as the location of "down current" and channel sampling locations .....	13
9. Current velocities and directions for the 13 stations sampled during the winter in and near the Georgetown Harbor DMDS .....	20
10. Current velocities and directions for the 13 stations sampled during the summer in and near the Georgetown Harbor DMDS .....	21
11. Distribution of mean grain size of sediments collected from the Georgetown DMDS and vicinity .....	25
12. Shepard's classification of sediment types at stations in the Georgetown DMDS and vicinity .....	27
13. Distribution of percent calcium carbonate content of sediments collected from the Georgetown DMDS and vicinity .....	29
14. Percentage contribution of major taxa to the species composition of beam trawl collections .....	33
15. Number of species collected at each station by beam trawl .....	35
16. Normal cluster dendrogram showing station groups formed using the Jaccard similarity coefficient and flexible sorting of beam trawl collections .....	38
17. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on beam trawl collections .....	40
18. Percentage contribution of major taxa to the number of species and number of individuals in grab samples from control, disposal, and "down current" sites .....	44
19. Comparison of the mean density of dominant macroinvertebrates from grab samples at control (CS), disposal (DS), and "down current" (DC) sites .....	47
20. Average values of several community structure parameters at control, disposal, and "down current" sites .....	50
21. Normal cluster dendrogram of benthic grab samples showing the five station groups formed using flexible sorting .....	52
22. Location of the winter samples among station groups resulting from normal cluster analysis .....	53
23. Location of the summer samples among station groups resulting from normal cluster analysis .....	54
24. Inverse classification hierarchy of grab collections and nodal diagrams showing constancy and fidelity of species groups among the sampling sites and seasons .....	55



## List of Tables

<u>Table</u>	<u>Page</u>
1. Geographic positions of sites sampled during the winter and summer, 1983 .....	15
2. Oceanographic parameters of water collected from the 7 winter and 9 summer stations sampled in and near the Georgetown Harbor DMDS .....	18
3. Maximum concentrations of various substances measured in sediment, water, and tissue samples collected from the vicinity of the Georgetown DMDS .....	22
4. Comparisons of hydrographic chemical analyses for Georgetown and Charleston Harbor areas .....	23
5. Statistical analysis of the grain size distribution for sediments from the Georgetown DMDS and vicinity .....	24
6. Percentages of sand, silt and clay in sediments from the Georgetown DMDS and vicinity .....	26
7. Calcium carbonate content of sediments from the Georgetown DMDS and vicinity ..	28
8. Comparisons of geochemical analyses of sediments for Georgetown and Charleston Harbor areas .....	31
9. Species ranked according to their frequency of occurrence (F) in $\geq 50\%$ of beam trawl collections .....	34
10. Summary of biomass (kg) for organisms collected with the beam trawl .....	37
11. Species groups resulting from numerical classification of data from samples collected by beam trawl .....	39
12. Number of species representing each of the major macroinvertebrate taxa in grab samples from control, disposal and "down current" sites .....	42
13. Number of individuals representing each of the major invertebrate taxa in grab samples from control, disposal, and "down current" sites .....	43
14. Relative abundance of the ten dominant species at each site during each season .....	46
15. Mean density of the dominant macroinvertebrates at control, disposal, and "down current" sites during each season .....	48
16. Species groups resulting from inverse cluster analysis of grab samples .....	56

## List of Appendices

<u>Appendix</u>	<u>Page</u>
1     Water current data of sites sampled during the winter and summer, 1983 ....	65
2     Hydrographic chemical analysis from the Georgetown DMDS area .....	66
3     Geochemical analysis of sediments from the Georgetown DMDS area .....	68
4     Taxa collected by beam trawl at control (CS), disposal (DS), and "down current" (DC) sites during winter (w) and summer (s) 1983 .....	71
5     Overall ranked abundance of macroinvertebrates collected during winter and the control site .....	75
6     Overall ranked abundance of macroinvertebrates collected during summer at the control site .....	80
7     Overall ranked abundance of macroinvertebrates collected during winter at the disposal site .....	84
8     Overall ranked abundance of macroinvertebrates collected during summer at the disposal site .....	87
9     Overall ranked abundance of macroinvertebrates collected during winter at the "down current" site .....	91
10    Overall ranked abundance of macroinvertebrates collected during summer at the "down current" site .....	93
11    Species diversity and faunal density of grab samples collected in the study area .....	95
12    Tissue sample analysis of <u>Busycon carica</u> from Georgetown DMDS area .....	96

## Acknowledgments

We wish to thank several people who assisted us in this study. Special thanks are due to Caroline O'Rourke and Marty Levisen who helped in all study phases. Their careful and diligent work in the field and laboratory greatly contributed to the timely completion of this study. Others who helped in the field and laboratory include the crew of the *Lady Lisa*, Pete Richards and Mike Schwartz, and MRRI staff members Jim Stribling, Penny Travis, Beth Roland, Tina Chance, Priscilla Hinde, and Kathy Austin. Nancy Beaumont typed all drafts of this report and Karen Swanson drafted all figures. Commonwealth Laboratory analyzed the contaminant samples for all parameters except trace metals. This report was reviewed by Victor Burrell, Rob Dunlap, Priscilla Hinde, Steve Morrison, Nick Roark and Jane Settle. Finally, we wish to thank Steve Morrison and John Carothers for their efforts in initiating this study, as well as for their part in the study design. We appreciate their encouragement and support of our work. This study was completed through funding under Contract #DACW60-83-C-0005 from the U.S. Army Corps of Engineers, Charleston District.

## Introduction

The Georgetown Ocean Dredged Material Disposal Site (DMDS) has been selected by the Corps of Engineers for release of sediments dredged from the channels associated with Georgetown Harbor. This disposal area is similar in depth and bottom type to the larger Charleston Harbor Ocean Disposal Area located approximately 87 km to the southwest. Although the latter area was sampled in 1978 for a baseline benthic and sedimentological characterization (South Carolina Wildlife and Marine Resources Department, 1979), no similar data base exists for the Georgetown DMDS. At the present time, the Georgetown DMDS is being used under interim approval by the Environmental Protection Agency (EPA). Continued use of this site requires more baseline information for final EPA site approval as authorized by the Marine Protection Research and Sanctuaries Act (MPRSA). To obtain the necessary data, the Corps contracted with the South Carolina Wildlife and Marine Resources Department (SCWMRD) to conduct benthic and sedimentological studies in and near the Georgetown DMDS. Specific objectives of this study were to:

- 1) Provide a review of existing information on the physical, chemical and biological conditions in the vicinity of the Georgetown DMDS and provide a succinct description of biological, recreational, or other resources that might be affected by ocean disposal;

- 2) Describe the mineralogical, textural, and chemical characteristics of the bottom sediments in the Georgetown DMDS, in a control site, in three stations "down current" of the DMDS, and in the navigation channel;

- 3) Describe the sediment bedforms present in the Georgetown DMDS, in the control area and in the three "down current" stations with regard to their size, orientation, and composition.

- 4) Ascertain whether the sediment characteristics of the DMDS and the stations "down current" have been altered by current disposal practices;

- 5) Describe temperature-depth, salinity-depth, and dissolved oxygen-depth profiles in the water column at all stations, and determine concentrations of metals, pesticides, PCB's, high molecular weight hydrocarbons, and the turbidities at four stations (one DMDS station, one control station, one "down current" station, and one entrance channel station);

- 6) Characterize the species composition and density of benthic communities in the DMDS, in the control site, and in the "down current" stations;

- 7) Determine the degree of bioaccumulation of pollutants in selected sedentary benthic organisms collected from the DMDS, control site, and "down current" stations;

- 8) Assess the effects of the present dredged material disposal practices on bottom communities in the DMDS and the three "down current" stations.

Results presented in this report provide baseline data necessary for appraising the effects of deposition of dredged material in the Georgetown ocean disposal area. The study also supplements existing knowledge of the physical, chemical, and biological characteristics of the nearshore sand bottom habitat off South Carolina.

## Review of Existing Information

The following survey of existing information is intended to provide a brief description of the environmental conditions and biological resources near the Georgetown DMDS. This information is compared with that described by the US EPA (1982) for similar disposal sites within the South Atlantic Bight.

### ENVIRONMENTAL AND BIOLOGICAL CHARACTERISTICS

#### Hydrography and Currents

A summary of previous studies which provide hydrographic data in the vicinity of the Georgetown DMDS is presented in Figure 1. Although most of these studies sampled areas either inshore or offshore of the proposed DMDS, the data generally support conditions described by the US EPA (1982) for nearshore South Carolina waters.

Surface water temperatures in the nearshore areas around Winyah Bay are usually within the seasonal variation of 10-25°C noted in surveys near Savannah, Charleston, and Wilmington (US EPA, 1982), although temperatures have been noted which exceed these extremes. For example, Mathews and Pashuk (1977, 1982) noted surface temperatures from 11-22°C in nearshore South

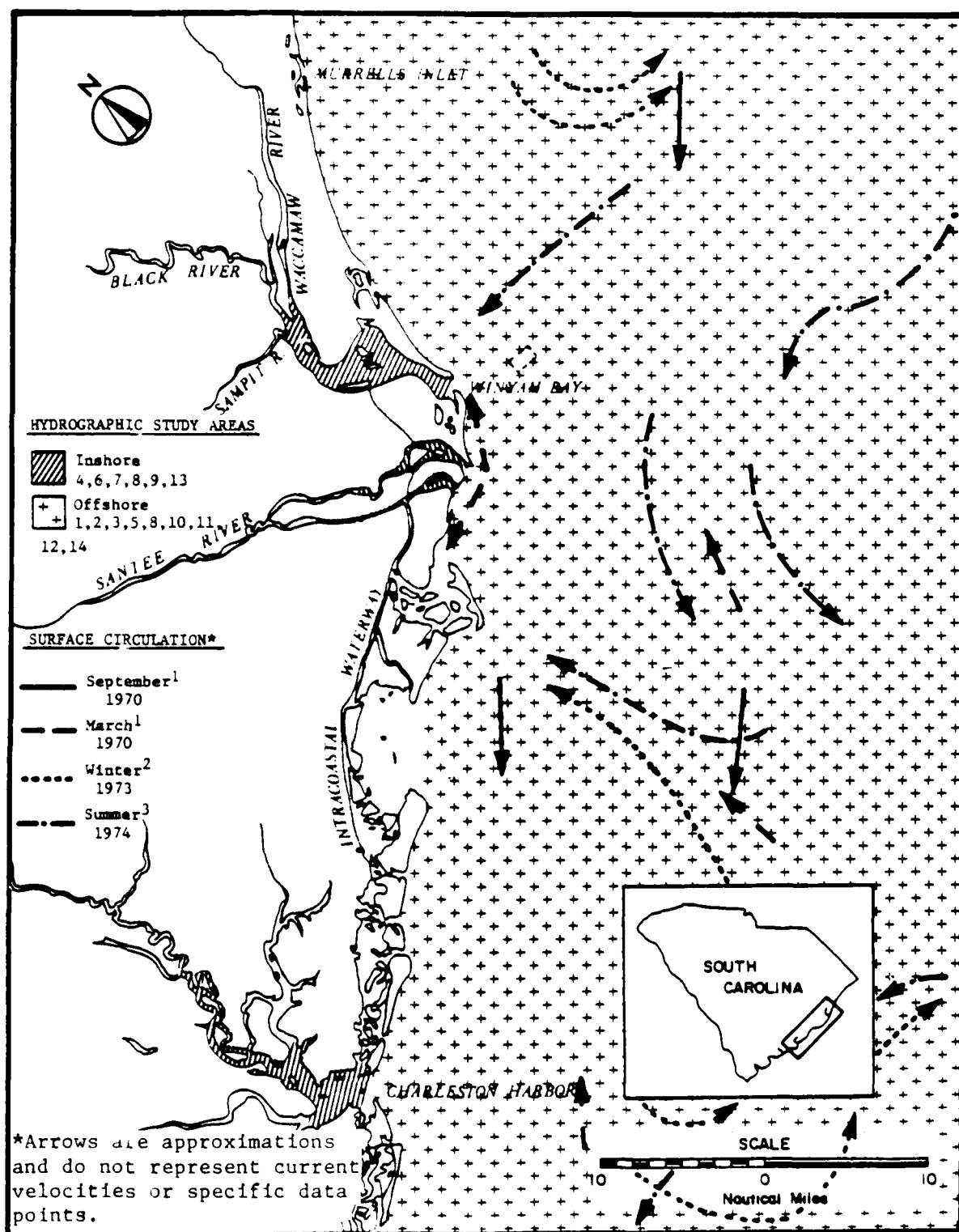


Figure 1. Location of hydrographic study areas and surface circulation patterns: <sup>1</sup>Bureau of Land Management (BLM), 1981; <sup>2</sup>Mathews and Pashuk, 1977; <sup>3</sup>Mathews and Pashuk, 1982; <sup>4</sup>Allen, et al., 1982; <sup>5</sup>Churgin and Halminski, 1974; <sup>6</sup>Hinde, et al., 1981; <sup>7</sup>Johnson, 1970; <sup>8</sup>Jones, Edmunds and Assoc., 1979a, 1979b, 1979c; <sup>9</sup>Mathews et al., 1981; <sup>10</sup>Minerals Management Service (MMS), 1982; <sup>11</sup>Science Applications Inc. (SAI), 1981a, 1981b; <sup>12</sup>SAI, 1983a, 1983b; <sup>13</sup>Shealy, 1974; <sup>14</sup>South Carolina Wildlife and Marine Resources Dept., 1979.

Carolina waters during four sampling periods or 1973 (Feb. - Nov.), but during 1974 (May - Nov.), temperatures varied from 18-27.5°C. Churgin and Halminski (1974) also presented water temperature data collected over a 50-year period from inshore and offshore waters of the region (31-34°N, 77-81°W) and noted surface temperatures of 11.4-29.3°C. Just inshore of the Georgetown DMDS, Allen et al. (1982) collected samples from Winyah Bay and observed surface temperatures ranging from 8.0-30.7°C at their station near the mouth of the Bay. Similarly, surface temperatures ranging from 11.4-29.3°C were noted in the mouth of the North Santee river (Mathews et al., 1981). Water temperatures in nearshore areas are primarily influenced by air temperature and river runoff.

The salinity and turbidity of water in the vicinity of the Georgetown DMDS is greatly influenced by water from Winyah Bay and, to some extent, by water from the Santee Rivers. Figure 1 shows the influence of Winyah Bay water on the salinity, turbidity and sedimentation in the DMDS. Waters from Winyah Bay are characterized by low salinities and temperatures in excess of the DMDS. In the mouth of the Santee river, Allen et al. (1982) noted salinities ranging from 21.4-22.0‰ and never recorded turbidity readings greater than 0.65 m. At a depth of 10 m in the Bay, Mathews and Stapanian (1978) observed extremely low salinities (21.4-22.0‰) in the mouth of the North Santee river. Mathews et al. (1981) noted salinities from 21.4-22.0‰ and Secchi disc readings which never exceeded 13 m. Further offshore, Mathews and Pashuk (1977, 1982) observed surface salinities which ranged from 32.5-34.0‰ in 1973 and 32.5-34.0‰ in 1974. Finally, over the 50-year period evaluated by Churgin and Halminski (1974), surface salinities in nearshore and offshore waters ranged from 31.4-35.9‰.

Due to the shallow depths in the Georgetown DMDS and its proximity to Winyah Bay and the Santee Rivers, vertical stratification of salinities in the area is dependent on tidal stage, wind disturbance and the amount of fresh water runoff. After the scheduled redirection of water flow from the Cooper River to the Santee Rivers, the hydrographic regime and vertical stratification in the area of the Georgetown DMDS may be considerably altered.

Current patterns in the vicinity of the Georgetown DMDS have not been well studied. Generally, longshore and nearshore currents run in a southerly direction along the South Carolina coast, although inshore currents become less well defined in the fall (Mathews and Pashuk, 1977). The strong tidal currents in Winyah Bay also have an influence on water flow in the area of the Georgetown DMDS. Generally, factors considered most important in influencing inner-shelf circulation patterns are wind and water density (Science Applications, Inc., 1983).

Wave energies generated along the South Carolina coast are low; waters are relatively still with a maximum fetch of 100 m. Waves less than 1 m are common along the

time and waves greater than 12 ft. are observed only at the time of the DMDS, 1983.

#### Bottom Sediments

Sediments in the nearshore area around Winyah Bay have not been well studied, but shelf sediments in this region appear to be primarily represented by medium- to coarse-grained sands (Pilkey et al., 1979; MMS, 1983). A summary of sedimentological conditions on the shelf off South Carolina is provided in Figure 3. In the entrance channel of Winyah Bay, Hinde et al. (1981) obtained limited information on sediments at three stations just outside the jetties. Two of the stations sampled in that study (CW01 and CW02) were mostly medium to coarse sands (> 90%) and the third station (CW03) was mostly silty clays.

With respect to sediment transport, Mathews et al. (1980) indicated that the north jetty of the Winyah Bay entrance channel traps the southerly littoral drift of sediments, resulting in deposition at the southern end of North Island. They also indicated that the original Winyah Bay ebb-tidal delta has largely been destroyed since completion of the south jetty. Stapor (1978) noted that between 1925 and 1964 South Island experienced a net deposition rate of 70,000 m<sup>3</sup>/yr. from onshore movement of sand under the influence of waves and tidal currents. If similar deposition patterns are occurring presently, it is possible that sediments disposed in the DMDS would move shoreward towards South Island. Additionally, some disposal sediments could also move back into the bay channels due to very strong tidal currents. Because of the shallow bottom depths in the Georgetown DMDS (2-6-11 m) and the proximity of this area to the entrance channel, wave action and tidal currents should be the primary factors influencing sediment distribution. Detailed bathymetric surveys in the area show no clear evidence of sediment mounding as a result of past disposal activities (see Figure 4 for a plot of an April 1983 survey).

#### Chemistry and Pollutants

Dissolved oxygen in nearshore and offshore waters off South Carolina were recorded over a 50-year period by Churgin and Halminski (1974). Values ranged from 3.8-6.1 ml/l, with highest average concentrations observed during the winter and lowest average concentrations observed in the summer. Near Winyah Bay, the dissolved oxygen in surface coastal waters ranged from < 4.0 ml/l to 6.5 ml/l during 1973-1974 with similar seasonal trends in concentrations (Mathews and Pashuk, 1977, 1982).

Nutrient input to the Georgetown DMDS area may be strongly influenced by waters from Winyah Bay. Although no seasonal data could be found for waters at the Bay entrance, Allen et al. (1982) collected samples at two stations in Winyah Bay and noted a bimodal pattern of nitrate and nitrite concentrations. Highest values were observed in late fall, winter, and spring; lowest values were noted in summer. Allen et al. (1982) also measured ammonia

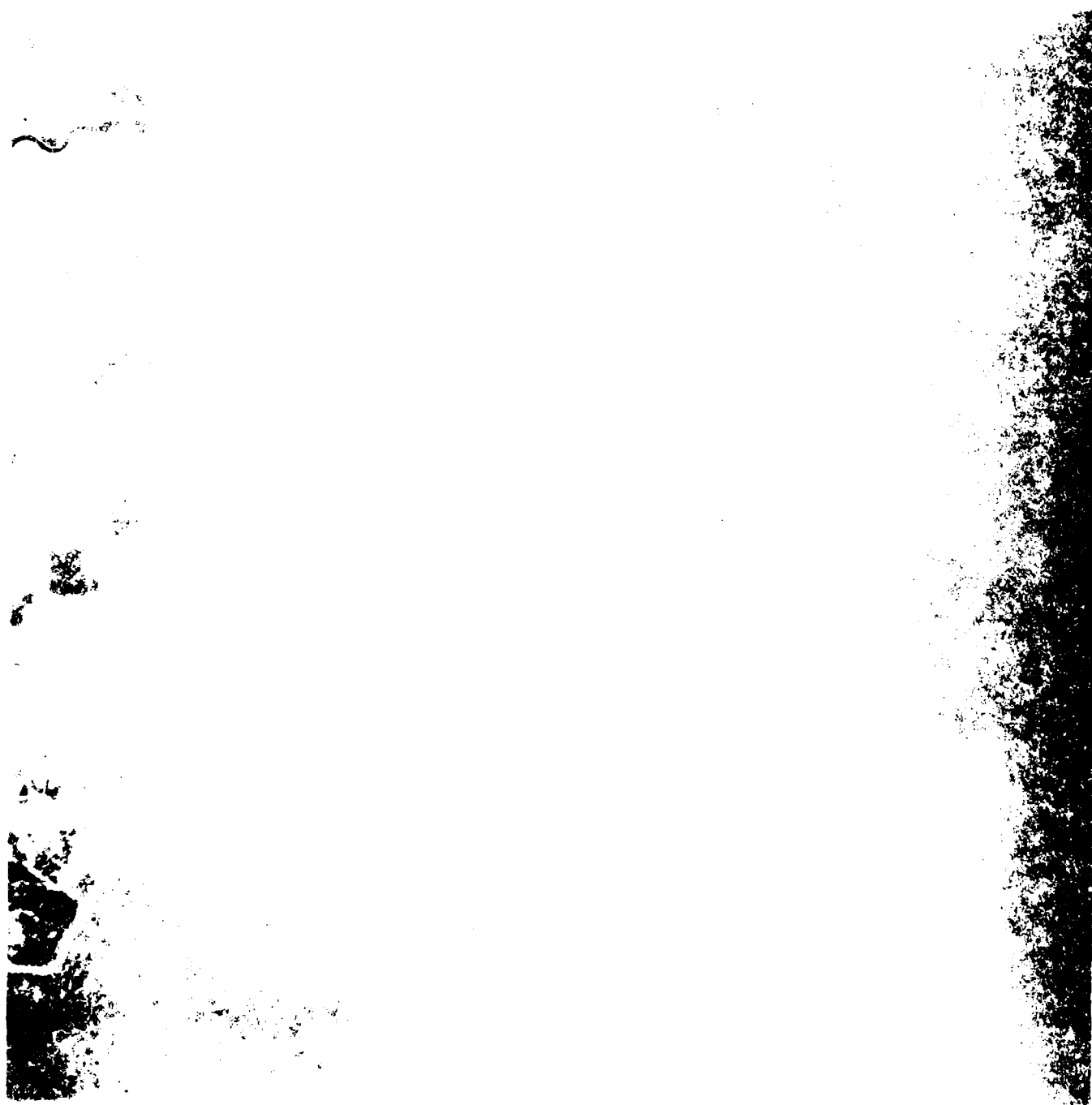


Table 1. Summary of water quality parameters of water collected from the 7 winter and 9 summer stations sampled in and on the coast of the Barents Sea.

W I N T E R									
Station	Depth	Temp. (°C)	Salinity (‰)	pH	Turbidity (FTU)	Station	Depth	Temp. (°C)	Salinity (‰)
DS03	Surface	8.7	27.2	10.4	5.5	DS03	8.5	8.9	33.9
	Middle	8.7	33.6	10.1	3.8		Middle	26.5	33.4
	Bottom	8.8	33.8	9.5	92.0		Bottom	26.7	34.3
DS13	Surface	8.5	29.7	9.3	4.8	DS13	12.0	8.8	34.5
	Middle	8.6	34.1	9.1	3.8		Middle	27.2	35.9
	Bottom	8.7	34.1	9.2	5.2		Bottom	27.1	35.5
CS02	Surface	9.2	30.0	9.2	4.6	CS02	9.5	8.8	35.3
	Middle	8.9	33.9	9.4	5.3		Middle	26.7	34.2
	Bottom	8.9	33.9	9.5	11.0		Bottom	26.8	34.3
CS13	Surface	8.9	32.2	9.4	2.2	CS13	10.5	8.9	27.9
	Middle	9.0	34.0	9.2	2.8		Middle	27.3	33.7
	Bottom	8.9	34.0	9.3	6.1		Bottom	27.0	34.3
DC01	Surface	9.4	33.1	9.0	2.0	DC01	9.5	8.1	34.3
	Middle	9.4	33.2	9.0	2.3		Middle	27.0	34.3
	Bottom	9.3	33.6	9.1	2.8		Bottom	27.1	34.4
DC02	Surface	9.0	29.6	9.2	4.3	DC02	7.3	6.2	32.6
	Middle	9.0	30.7	9.0	6.5		Middle	26.8	34.3
	Bottom	9.0	33.6	9.9	13.0		Bottom	26.7	33.8
DC03	Surface	8.5	21.9	9.8	8.0	DC03	7.5	8.9	34.2
	Middle	8.7	33.3	8.8	12.0		Middle	27.0	34.2
	Bottom	8.9	33.6	9.2	27.0		Bottom	27.4	35.3
CH01	Surface	8.5	29.0	9.8	8.0	CH01	7.5	7.7	34.1
	Middle	8.7	33.3	8.8	12.0		Middle	29.0	34.1
	Bottom	8.9	33.6	9.2	27.0		Bottom	29.9	34.5
CH02	Surface	8.5	27.3	9.8	5.8	CH02	9.5	8.8	33.6
	Middle	8.7	33.3	8.8	13.0		Middle	27.1	33.7
	Bottom	8.9	33.6	9.2	28.0		Bottom	26.9	34.1

the frequency with which species of a particular group are found in a given collection group and fidelity measures the degree to which species are restricted to a particular collection group.

For trawl biomass estimates, a Model I two-way analysis of variance without replication was used to determine whether the mean log-transformed biomass of beam trawl collections differed significantly between seasons (winter, summer) and among areas (disposal, control, and "down current"). Due to non-normality and heterogeneous variances, a logarithmic [ $\log_{10}(x+1)$ ] transformation was used on each variate prior to calculation of means and analysis of variance.

Infaunal community structure based on grab collections was evaluated using several indices of species diversity and cluster analysis. Species diversity was calculated on the pooled samples collected during each station visit using Shannon's diversity index ( $H'$ ), species richness ( $SR$ ), and evenness ( $J'$ ) (Margalef, 1958; Pielou, 1975). Total number of species and faunal abundance were also evaluated. Normal and inverse cluster analyses were conducted on log-transformed abundance estimates from pooled (by station) grab samples using the Bray-Curtis similarity coefficient (Boesch, 1977). As with the trawl cluster analyses, a flexible sorting strategy with a standard cluster intensity coefficient ( $\beta$ ) of  $-0.25$  was used in both the normal and inverse analysis. Species which occurred in fewer than 7% of the 130 grab samples were deleted from the data set since rare species usually do not have easily defined distribution patterns and can confuse interpretation of cluster analysis. In all cases, species deleted because of rare occurrence were also rare in abundance. In order to accurately compare winter and summer data, bryozoans were also deleted prior to cluster analysis, since they were not enumerated during winter. Following normal and inverse analyses, a nodal analysis was performed using fixed station groups (DMDS, control, "down current", by season) and the inverse species groups to obtain estimates of fidelity and constancy as defined above.

#### BIOACCUMULATION ASSESSMENT

Specimens of the knobbed whelk, *Busycon carica*, were collected in the DMDS, control and "down current" areas for bioassay analysis. This mollusk was the only relatively sedentary organism which was present in all three sampling areas and was large enough to obtain sufficient biomass for analysis. The species is also commercially harvested in South Carolina. All *B. carica* specimens were collected from beam trawl samples taken in the three areas. After collection, specimens were preserved and analyzed according to the procedures outlined by Pequegnat, et al. (1981). All chemical contaminants, except oil and grease, which were analyzed in water samples were analyzed in the tissue samples.

## Results and Discussion

### HYDROGRAPHY

Water column chemistry in the study area can be influenced by runoff, nearshore and Gulf Stream current patterns, suspended sediments, eolian transport and other factors. As a result, the water chemistry may vary considerably on a temporal basis. Runoff from Winyah Bay and the Santee Rivers decreases salinities, increases turbidities and deposits fine sediments offshore. Normal runoff from these systems can be very high, with flows from the combined river systems being  $> 15,000$  cfs (U.S. Geological Survey, 1979). In addition, a longshore drift to the southwest is usually present during summer months, while a northeasterly flow exists during winter months (Mathews and Pashuk, 1984). Therefore, depending on season and environmental conditions, waters from Winyah Bay may move either to the north or south along the coast as well as spread out towards deeper waters.

### Oceanographic Parameters

Values recorded for the oceanographic parameters measured in this study generally agree with historic readings, although some of the salinities recorded during the winter cruise were particularly low. In that season, surface salinities were as low as 21.9 ‰ at station DC03 and  $< 30$  ‰ at DC02, DS03 and DS13 (Table 2). These low salinities were the result of runoff from a massive rainstorm which preceded the winter sampling cruise. Summer salinities were generally higher than values observed during winter. Except for the station in Winyah Bay (CH01) which had salinities  $< 15$  ‰ from surface to bottom, only one station (CS13) had surface water  $< 30$  ‰. During a two-year study in Winyah Bay, salinities at a station 2 miles upstream from the mouth averaged  $< 15$  ‰ and ranged from  $< 2$  ‰ to  $> 30$  ‰ (Mathews and Shealy, 1982). Nearshore surface salinities off Winyah Bay are typically  $> 30$  ‰ (Mathews and Pashuk, 1977, 1982, 1984).

Dissolved oxygen (DO) and water temperatures were also within normal ranges and DO was inversely related to temperature (Table 2). Both summer and winter DO concentrations were representative of the seasons sampled, with higher values ( $> 10$  mg/l) being found in cold waters ( $< 9.0^{\circ}\text{C}$ ) and lower values ( $< 6$  mg/l) found in warmer waters ( $> 26.5^{\circ}\text{C}$ ). Water temperatures were slightly cooler than usual for summer and winter, but not abnormally so (Mathews and Pashuk, 1984).

For all stations, turbidities were  $\leq 8.0$  FTU in surface samples and  $\leq 13.0$  FTU in mid-water samples (Table 2). Highest values were normally encountered in bottom waters, where



to provide a cumulative frequency curve from which the statistical parameters were calculated according to Folk (1965).

A pipette analysis was performed on those samples which contained an appreciable amount of fine-grained material. These samples were dispersed by adding 100 ml of 1N sodium metaphosphate  $[(NaPO_3)_x \cdot Na_2O]$  as a dispersing agent and agitated using an ultrasonic dismembrator for 15 minutes. After complete deflocculation was achieved, the samples were wet-sieved through a #230-mesh stainless steel screen to separate the sand from the silt and clay. The silt and clay fraction was then transferred to a 1000-ml graduated cylinder and the sample was pipetted using the withdrawal times and depths as outlined by Folk (1965). The percentages of sand, silt and clay were also recorded for these samples and plotted on a standard sediment-type triangular diagram.

Subsamples of sediment cores were also collected for analysis of the following parameters: Total organic carbon (TOC), chemical oxygen demand (COD), Kjeldahl nitrogen, nitrite nitrogen as  $NO_2$ , nitrate nitrogen as  $NO_3$ , oil and grease, lead, zinc, mercury, soluble phosphorus as  $PO_4$ , total phosphorus as  $PO_4$ , iron, cadmium, arsenic, chromium, nickel, copper, PCBs (as Arochlor 1254), Heptachlor, DDT and metabolites, Endrin, Dieldrin, BHC, Mirex, Methoxychlor, Chlordane, Toxaphene and high-molecular-weight hydrocarbons. All samples were preserved, processed and chemically analyzed using the procedures described by Pequegnat et al. (1981) and outlined for hydrographic analyses, except that metals were measured in two ways: after total extraction (bulk chemical analysis) and after partial extraction with 0.1N HCl. A second set of samples was collected from three stations (CS09, DS08, DC02) and preserved in the same manner for delivery to the Charleston District Corps of Engineers.

Sediment samples were not collected during the winter season. However, qualitative observations were made for each grab sample collected for benthos.

During summer, additional sedimentological studies included diver observations of the bottom. Unfortunately, very strong currents and extremely poor visibility drastically reduced the effectiveness of this effort and detailed results are not presented.

#### BENTHIC COMMUNITY ASSESSMENT

Macrofauna were sampled during both seasons at all randomly selected sites in the OMDS and control areas, as well as at the three "down current" stations. Prior to water chemistry or grab sampling during the winter, qualitative epifaunal samples were obtained at each of the 13 stations using a beam trawl similar to that described by Pequegnat et al. (1981). One tow was made in a north-south direction through

each station, with all tow lengths standardized to 0.5 km based on Loran-C positioning. Similar beam trawls were made at the same 13 sites in summer, but only after sediment, grab and water chemistry sampling was completed in order to avoid disturbance of the bottom. Organisms obtained in each tow were preserved in 10% seawater-formaldehyde for later identification. Biomass estimates were also obtained for each sample.

Quantitative benthic samples of macrofauna were collected using a Smith-McIntyre grab while the research vessel was anchored on station. Five replicate samples were collected at each of the 13 stations (in addition to the separate sediment samples) both seasons. After measuring the volume of each grab sample, the collected material was washed through a 1-mm sieve. Organisms and sediment remaining on the sieve after washing were removed and preserved in 10% seawater-formaldehyde with rose bengal stain. Samples were then brought to the laboratory and organisms were sorted, identified to the lowest taxonomic level, and counted.

For qualitative collections by beam trawl, diversity was evaluated by comparing the number of species ( $s$ ) among stations. The Kruskal-Wallis one-way analysis by ranks (Siegel, 1956) was used to determine whether median  $s$  differed significantly among the three areas sampled: disposal, control and down current. A significant difference in  $s$  between winter and summer was evaluated by the Mann-Whitney U-test (Sokal and Rohlf, 1982).

Qualitative data on the presence or absence of species collected with the beam trawl were analyzed by cluster analysis to determine patterns of similarity among stations and species. Only species which occurred in two or more trawl collections were included in this analysis.

Species and collections were classified using a flexible sorting strategy (Lance and Williams, 1967) with a cluster intensity coefficient ( $\beta$ ) of -0.25. The Jaccard similarity coefficient (Clifford and Stephenson, 1975) was used with presence/absence data obtained from beam trawl collections.

Normal and inverse classifications were produced for combined seasonal data. The result of normal classification was a dendrogram in which collections were clustered based on their degree of similarity in terms of species presence. Inverse classification produced a dendrogram in which species were clustered based on their degree of similarity in terms of presence in collections (Williams and Lambert, 1961).

Subsequent to cluster analysis, species and station groups were chosen using a variable stopping rule (Boesch, 1977). Nodal analysis was then used to express the degree of species/site group coincidence in terms of ecological constancy and fidelity. Constancy expresses

Table 1. Geographic positions of sites sampled during the winter and summer, 1983.

SITE	STATION	SEASON	LATITUDE	LONGITUDE
DISPOSAL	DS03	winter, summer	33° 10.72'N	79° 7.23'W
	DS06	winter, summer	33° 10.72'N	79° 6.80'W
	DS08	summer	33° 10.97'N	79° 6.37'W
	DS09	winter	33° 10.72'N	79° 6.37'W
	DS10	summer	33° 11.22'N	79° 5.92'W
	DS11	winter	33° 10.97'N	79° 5.92'W
	DS13	winter, summer	33° 11.22'N	79° 5.48'W
CONTROL	CS02	winter, summer	33° 12.17'N	79° 7.05'W
	CS04	winter	33° 12.42'N	79° 6.62'W
	CS05	summer	33° 12.17'N	79° 6.62'W
	CS09	winter, summer	33° 11.92'N	79° 6.17'W
	CS10	winter	33° 12.42'N	79° 5.73'W
	CS11	summer	33° 12.17'N	79° 5.73'W
DOWN CURRENT	CS13	winter, summer	33° 12.42'N	79° 5.30'W
	DC01	winter, summer	33° 10.28'N	79° 6.92'W
	DC02	winter, summer	33° 9.53'N	79° 7.47'W
CHANNEL	DC03	winter, summer	39° 10.28'N	79° 7.88'W
	CH01	summer	33° 13.20'N	79° 11.35'W
	CH02	summer	33° 11.57'N	79° 8.0'W

station was located between the DMDS and onshore resources. Coordinates for these stations, collectively referred to as "down current" stations (Figure 3), are listed in Table 1. Two additional stations were located in the entrance channel, one near the outer limit of the south jetty and one farther up the channel near the Georgetown lighthouse (Figure 3). These channel stations were only sampled during the summer season.

#### HYDROGRAPHIC ASSESSMENT

Temperature, salinity, dissolved oxygen and turbidity measurements were obtained at surface, midwater and bottom depth intervals using Van Dorn bottles. A standard thermometer was used for temperature measurements and Yellow Springs Instrument SCT-DO meters and probes (Model 33 SCT, Model 51 DO) were used to measure salinity and dissolved oxygen. The accuracy of these instruments was verified prior to sampling by separate measurements of a surface water sample taken at each site using a backup set of instruments. Turbidity samples were brought to the laboratory for measurement on a Hach Model 2100A turbidimeter. All water parameters were measured during winter and summer periods at nine stations: two in the DMDS area (most landward and most seaward stations), two in the control area (most landward and most seaward stations), the three "down current" stations, and the two channel stations (summer only).

During the summer sampling period, additional water samples were collected at four stations (CS09, DS08, DC02 and CH02) for analyses of oil and grease, lead, zinc, mercury, cadmium, arsenic, chromium, nickel, copper, PCBs (as Arochlor 1254), Heptachlor, DDT and metabolites, Endrin, Dieldrin, BHC, Mirex, Methoxychlor, Chlordane, Toxaphene and high-molecular-weight hydrocarbons. These samples were collected from bottom waters using a nonmetallic, acrylic, Van-Dorn type water bottle with silicon-coated end caps. The samples were collected, processed and analyzed in the laboratory using methods described by Pequegnat et al. (1981). In the case of trace metals, the alternative procedures described in Federal Registers (Vol. 44, No. 22, p. 69568; Vol. 44, No. 244, p. 75028; 1979) were used. Nutrients were measured using a Bausch and Lomb Model 70 spectrophotometer. Pesticides and hydrocarbons were measured using a Hewlett-Packard gas chromatograph, and oil and grease was measured by freon extraction. All metals were analyzed either on a Perkin-Elmer Model 306 or Model 460 atomic absorption spectrophotometer, with the Model 306 being used for all flame analyses plus the mercury flameless analysis, and the Model 460 being used for graphite furnace (flameless) analyses.

Current measurements were obtained at the 13 stations outside the channel during both seasons. An Endeco Model 110 current meter was used to obtain surface and bottom

estimates of current speed and direction. All measurements were obtained while the research vessel was anchored on station. Surface measurements were obtained at approximately 3-m depth to insure that the instrument was at least 1 m below the vessel's keel. Bottom measurements were obtained approximately 1 m above the bottom. Intermediate current measurements were not taken due to the shallow water depths at the stations.

General meteorological and related observations were noted during every station visit. Observations included estimates of wind direction and speed, barometric pressure, cloud cover, precipitation, wave height and wave direction.

#### SEDIMENTOLOGICAL ASSESSMENT

Bottom sediments were collected at all 15 stations during the summer season using a Smith-McIntyre grab. This grab is designed to take an intact sample of offshore sandy sediments with minimal washout. Sediments were removed from the center of the first undisturbed grab sample collected at each site using methods described by Pequegnat et al. (1981).

Sediment subsamples for granulometric analyses were allowed to air dry and then disaggregated using a rubber-tipped pestle and split into two representative portions. One half of each sample was used for mineralogical analysis and the other for textural analysis. Those samples which contained significant quantities (more than a few percent) of material finer than  $4\phi$  (0.0625 mm) were analyzed by both coarse sieving and pipette techniques.

A mineralogical analysis was performed on each of the samples to determine the percent weight of quartz and calcium carbonate (shells). Acid leaching using dilute (10%) HCl was utilized to determine the calcium carbonate content of the samples. Those samples which contained a high percentage of clay (making them very compact) were placed in distilled water and disaggregated using an ultrasonic dismembrator. After sample disaggregation was achieved, 200 ml of dilute HCl was added to dissolve the carbonate constituents. Upon complete leaching, the weight of the dried filtrate was determined and the percentage of acid-soluble calcium carbonate was calculated for each of the samples.

A grain size analysis of the bottom sediments was performed to determine the mean grain size, sorting, skewness and kurtosis for the samples. Grain size determinations were made using a Ro-tap mechanical shaker and 1/2  $\phi$  interval screens. The weight of the sediment retained on each screen (sieve fraction) was recorded. The weight percent and cumulative weight percent for each of the size classes were determined. These data were then plotted

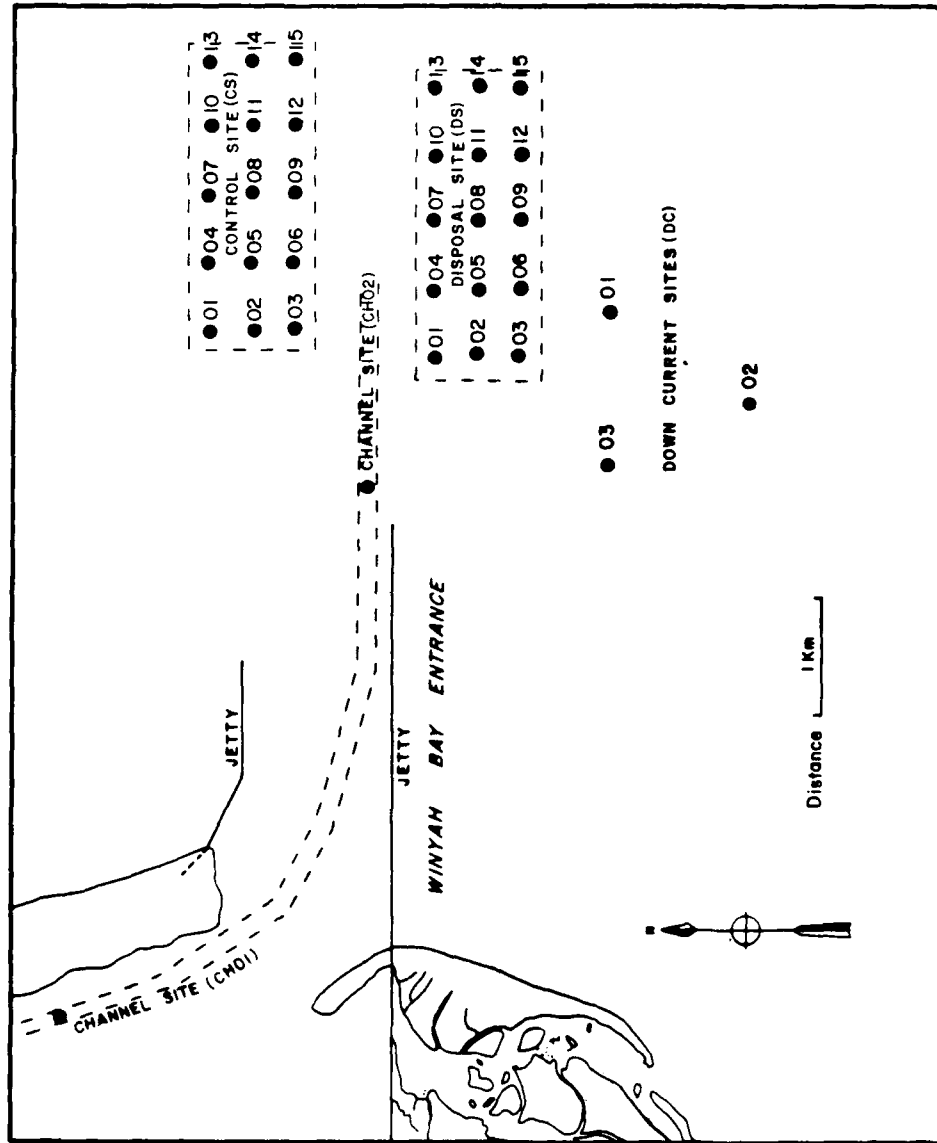


Figure 8. Map showing location of the 15 possible sampling locations in the control and DMDS sites, as well as the location of "down current" and channel sampling locations.

since there are no piers or reefs nearby (Figure 3). Recreational fishing around the entrance channel jetties to Winvash Bay may be affected temporarily by increased water turbidity.

#### Natural and Artificial Reefs

The approximate locations of artificial reefs in the study region are identified in Figure 5. The "Georgetown Wreck" is the reef nearest the DMDS and is located approximately 5 miles to the northeast (Myatt, 1978). The only other reefs near the DMDS are the "Hector" and "City of Richmond" wrecks located approximately 4 miles to the south-southeast. It is unlikely that these reefs would be negatively influenced by disposal operations in the Georgetown DMDS, due to their distance from this site. Natural hard bottom reefs are not known to occur in the area around Winvash Bay; rather, most natural reefs are located further offshore (Henry and Giles, 1974; Miller and Richards, 1980; SCWMD, 1982), or farther to the north (Parker et al., 1979). "East Bank", a shoal located approximately one mile to the southwest of the DMDS, may be a shell bank supporting sessile reef biota; however, no studies have been done on this bank.

#### Endangered Species

Habitat locations for endangered species in the study area are summarized in Figure 6. The two most important species that might be affected by offshore disposal operations are the shortnose sturgeon (*Acipenser brevirostrum*) and the loggerhead turtle (*Caretta caretta*). Shortnose sturgeon have been collected around the jetties in winter (Smith, T.I.J., pers. comm.), but this species spends most of its life in freshwater (Leland, 1968). The incidence of loggerhead turtle nesting is moderate on North Island and high on South Island (Davis et al., 1980). In South Carolina, adult females come ashore to nest from mid-May to mid-August, and many appear to use the waters around the DMDS during their movements (Hopkins and Murphy, 1981). The influence of disposal activities on turtle movements are not known, but effects would probably be limited to localized interruption of onshore migration rather than any direct impact on beach nesting areas.

#### Other Resources

The location of marine historical features, preserves, wildlife centers, recreational beaches and ports are shown in Figures 6 and 7. The only nearby historical feature, other than the shipwrecks mentioned previously, is the "Sir Robert Peel" wreck located just inshore of the DMDS. No historical features are known to be located within the DMDS. Although there are numerous preserves and wildlife centers along the coast, offshore disposal of sand sediments in the Georgetown DMDS is not expected to have

any significant impact on the wildlife in those areas. Furthermore, disposal is not anticipated to adversely affect the nearest recreational beaches, which are located approximately 15 miles to the north of Winvash Bay. Finally, shipping to the port of Georgetown would not be impeded since the disposal area is located outside of the shipping channels.

## **Methods**

### **LOCATION OF STUDY AREAS**

The general location of stations sampled in this study is shown in Figure 8. Stations located in the Georgetown DMDS were within the boundaries defined by a rectangle having the following corner coordinates:

- |                              |                              |
|------------------------------|------------------------------|
| (1) 33°11'18"N<br>79°07'20"W | (2) 33°11'18"N<br>79°05'23"W |
| (3) 33°10'38"N<br>79°07'21"W | (4) 33°10'38"N<br>79°05'24"W |

The control sites selected for study were also located within a rectangular area situated just north of the entrance channel to Georgetown Harbor. Water depths in this area were similar to the DMDS and the control area was approximately the same distance from shore. Coordinates of the corners of the control area were:

- |                              |                              |
|------------------------------|------------------------------|
| (1) 33°12'30"N<br>79°07'09"W | (2) 33°12'30"N<br>79°05'12"W |
| (3) 33°11'50"N<br>79°07'09"W | (4) 33°11'50"N<br>79°05'12"W |

Within both the DMDS and the control sites, 15 points were located so that there were three rows of 5 equally spaced points (Figure 8). The four corner points in each area were located approximately 150 m inside the site boundaries. The east-west separation of points was approximately 680 m and the north-south separation of points was approximately 460 m. Five points from each of the above areas (DMDS, control) were randomly selected during winter (February 1983) and summer (July 1983) sampling periods using a stratified random selection technique; i.e., one point was randomly selected from each of the 5 columns of 3 points. This sampling design insured adequate sampling of each area for a complete representation of the bottom. The random sampling design also permitted appropriate statistical analyses. Stations selected for sampling during each season are listed in Table 1. All stations were located using Loran-C positioning with a Loran plotter system.

Based on the guidelines of Pequegnat et al. (1981) and on limited current data, two stations were located in the general direction of predominant nearshore currents, and a third

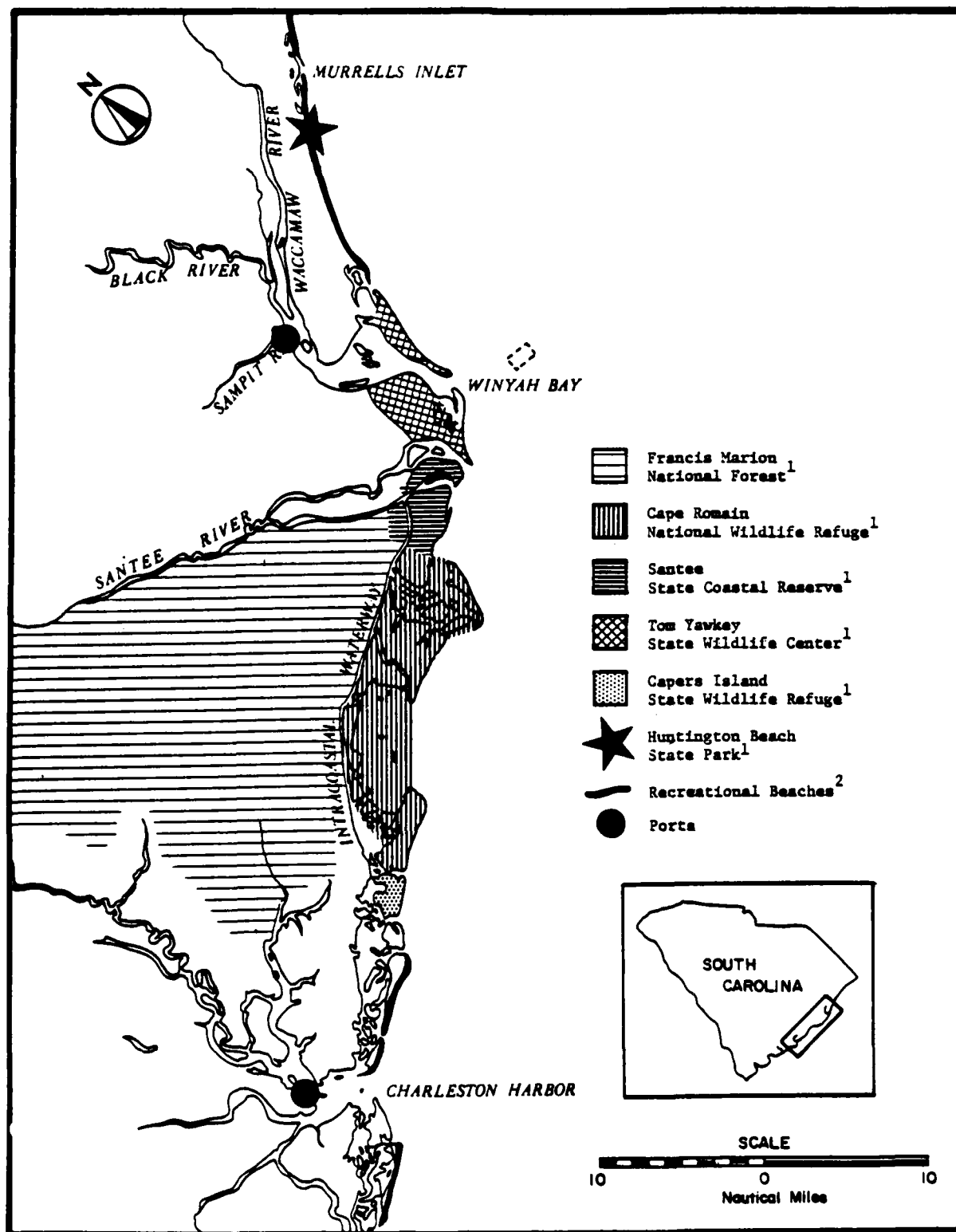


Figure 7. Location of preserves, wildlife centers, beaches and ports:  
<sup>1</sup>Davis, et al., 1980; <sup>2</sup>BLM, 1981.

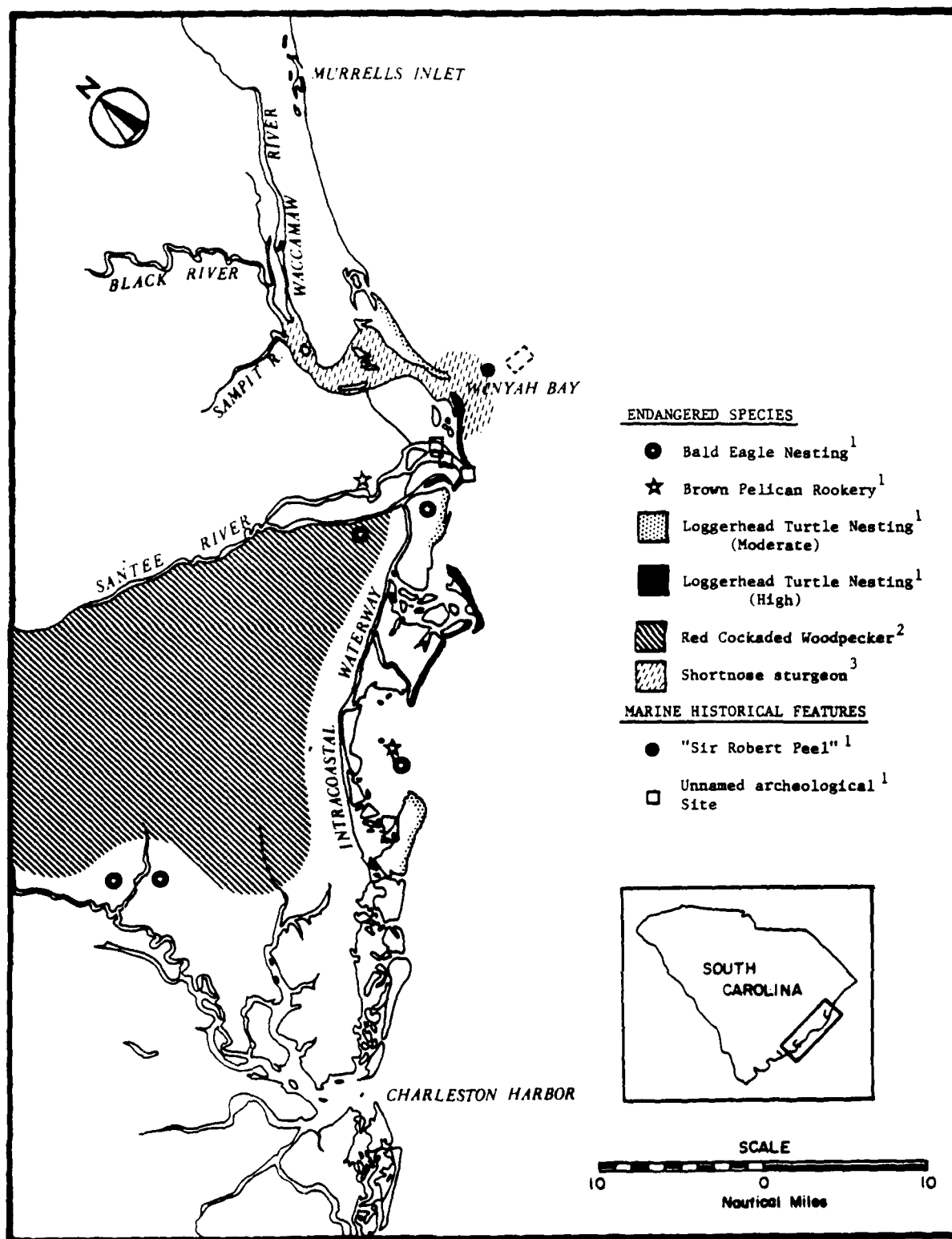


Figure 6. Location of endangered species and marine historical features:  
<sup>1</sup>Davis, et al., 1980; <sup>2</sup>BLM, 1981; <sup>3</sup>SCWMRD, unpublished.

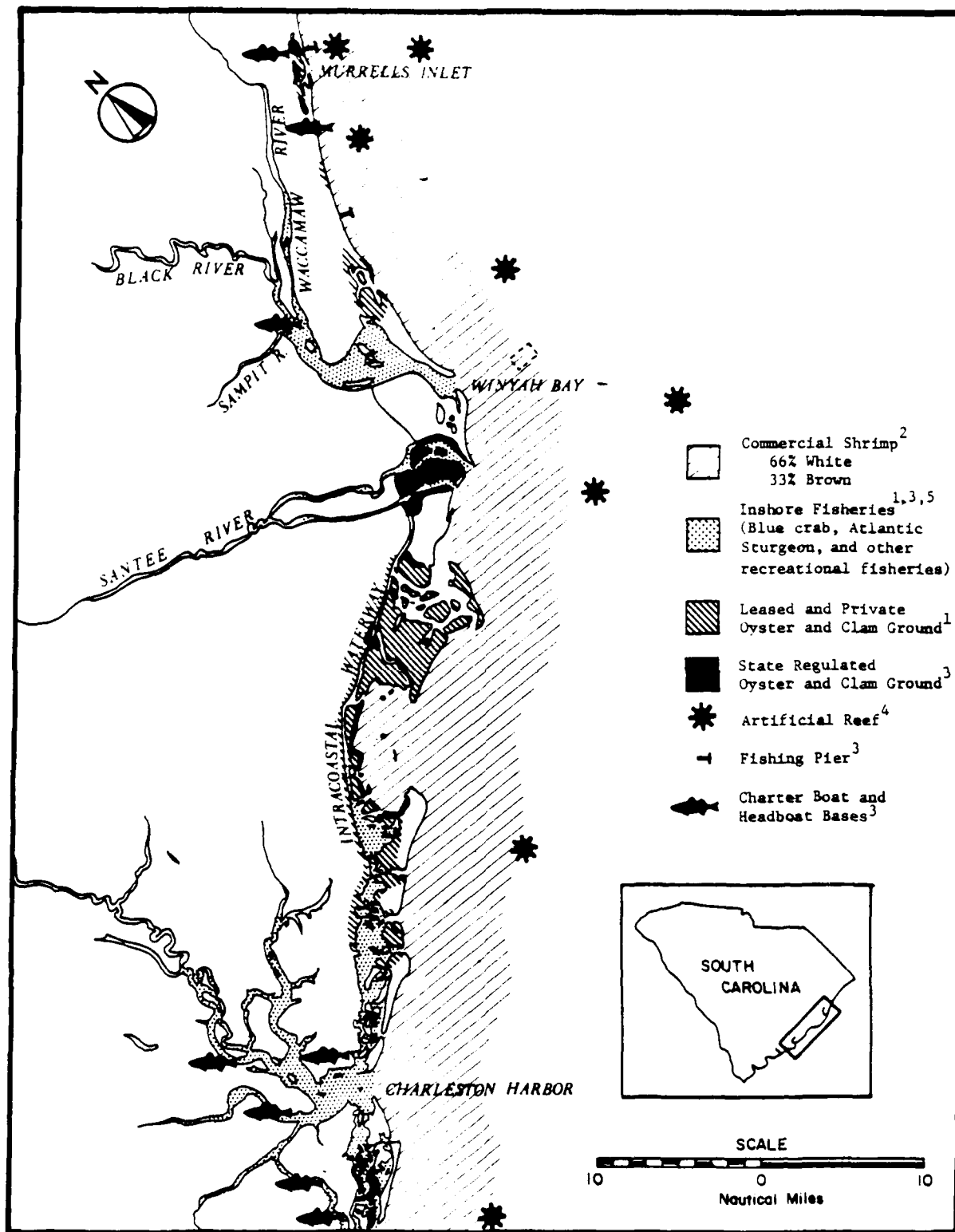


Figure 5. Location of commercial and recreational fisheries resources:  
<sup>1</sup>Davis, et al., 1980; <sup>2</sup>BLM, 1981; <sup>3</sup>Moore, 1980; <sup>4</sup>Myatt, 1978;  
<sup>5</sup>Smith, 1983.



(Ictalurus catus), Atlantic croaker (Micropogonias undulatus), hog choker (Trinectes maculatus) and tonguefish (Symphurus plagiosa). Hinde et al. (1981) also collected these species and numerous others.

Biological data collected from the above studies generally support the information presented by the US EPA (1982) for the South Atlantic Bight. However, exceptions are noted with respect to infaunal assemblages (see Results and Discussion).

#### LOCATION IN RELATION TO LIVING AND NON-LIVING RESOURCES

##### Fisheries and Shellfish Grounds

Commercially and recreationally important species found in the estuarine and coastal marine areas around Winyah Bay include shrimp (Penaeus setiferus, P. aztecus), blue crabs (Callinectes sapidus), oysters (Crassostrea virginica), clams (Mercenaria mercenaria), Atlantic sturgeon (Acipenser oxyrinchus) and other finfish species such as black sea bass (Centropristis striata), porgy (Pagrus pagrus, Calamus leucosteus), grouper (Mycteroperca microlepis, M. phenax), red snapper (Lutjanus campechanus), mackerel (Scomberomorus cavalla) and many others. The general location of these fisheries is summarized in Figure 5.

Commercial shrimping occurs primarily within 3 miles of shore; however, around the entrance to Winyah Bay shrimpers often work further offshore (3-5 mi.). In South Carolina, shrimping occurs from May through December with peak catches in September and October. Incidental catches from the shrimp fishery are also economically important and include many finfish species (Keiser, 1977). Shrimp populations in the area around the disposal site might decline during periods of disposal due to the associated increased turbidity; however, the effects of offshore disposal of dredged materials on shrimp populations have not been adequately studied.

The mollusk fisheries are also seasonal, beginning in September and ending in May. In Georgetown County, clam landings were of much greater economic value than oyster landings during 1982 (SCWMRD, unpubl. data). Clam harvesting in the Santee estuary increased considerably after the introduction of hydraulic harvesting in 1974 (McKenzie et al., 1980). The scheduled redirection of waters from the Cooper River estuary, however, is expected to largely destroy shellfish grounds in the Santee estuary. Disposal of offshore channel sediments in the Georgetown DMDS

will probably not have much effect on the inshore shellfish grounds, since they are not close to the DMDS (Figure 5).

The amount of blue crabs caught in Georgetown County was greater during spring, summer and fall months than during winter, with greatest catches during March of 1982 (SCWMRD, unpubl. data). As noted for clam and oyster beds, it is unlikely that the blue crab fishery in the Winyah Bay and Santee River estuaries will be influenced by offshore disposal of sand sediments.

Commercial finfish landings in Georgetown County totaled more than two million pounds (SCWMRD, unpubl. data). As noted earlier, many of the fishes landed include black sea bass, grouper, snapper, porgy and other reef fishes. These fishes are associated primarily with offshore hard bottom reef habitats, which have not been found near the Georgetown DMDS.

Winyah Bay is the location of the biggest Atlantic sturgeon fishery in the Sea Islands coastal region (McKenzie et al., 1980) and almost 50,000 lbs. of sturgeon were landed in Georgetown County during 1982 (SCWMRD, unpubl. data). These fish are generally caught with nets set in the ocean near the jetties. Due to the proximity of this fishery to the Georgetown DMDS, there is the possibility of negative effects if disposal activities take place when sturgeon are abundant near the DMDS. Although specific effects of disposal operations on sturgeon populations have not been documented, Morton (1977) noted mortality and displacement of other fishes resulting from increased turbidity. Leland (1968) indicates that sturgeon gather at the inlets during February and March and then move up the inlets as temperatures rise. The fishing season around the jetties begins 15 February and ends 15 April, although sturgeon are still in the area after that date (Smith et al., 1982; SCWMRD, unpubl. data). Most sturgeon landings in Georgetown County occurred from February to June during 1982, with peak landings occurring during March and April. Negative impacts on the sturgeon fishery could be minimized if disposal operations are avoided during the period from mid-February through May.

Recreational finfish catches are primarily from head-boat charters to offshore reefs, fishing on private boats for reef fish and large pelagic species, and pier fishing. Most recreational finfish catches would not be influenced by disposal activities in the Georgetown DMDS

levels and noted highest concentrations in summer and early fall and lowest concentrations in winter.

Jones, Edmunds and Associates, Inc. (1979c) measured concentrations of nutrients, trace metals, and organic pollutants in waters from the Georgetown DMDS, as well as from four stations in the entrance channel. They did not detect any pesticides or PCBs in their samples, nor did they observe high concentrations of nutrients or trace metals among the samples tested. However, they did measure cadmium concentration in DMDS waters which was 22 times the limiting permissible concentration.

Bed sediments in Winyah Bay were analyzed for trace metals and pesticides by Johnson (1970). He concluded that Winyah Bay is relatively unpolluted by pesticides, although he found some trace metals. Sediments in the Georgetown DMDS have not been analyzed for pesticides or trace metals prior to the present study, but Van Dolah et al. (1983) noted only low concentrations of metals and nutrients in sediments collected from the Charleston DMDS.

#### Biology

Phytoplankton and zooplankton communities have not been well studied in the nearshore coastal waters of South Carolina. The limited data available for these planktonic groups is best summarized by Sandifer et al. (1980). In Winyah Bay, Allen et al. (1982) examined chlorophyll concentrations and noted highest values in summer months (July - Sept.). Just north of Winyah Bay, Lonsdale and Coull (1977) examined the seasonal composition of zooplankton communities in North Inlet. They noted that copepods dominated the community (64-69% of total density) with the most abundant species being Parvocalanus crassirostris, Acartia tonsa, Oithona colcarva, and Euterpina acutifrons. The US EPA (1982) also notes that inshore waters are dominated by copepods.

The potential effects of offshore disposal on plankton communities around the Georgetown DMDS cannot be easily defined, but it is likely that increased turbidities from disposal operations would have some localized impacts. Of most concern are the nauplii of certain species of shrimp (Penaeus setiferus, P. aztecus) and larval ichthyofauna. Short-term disposal of sand sediments should not have an enduring impact on these taxa, but longer-term disposal or disposal of silts and clays might be more severe in their effects.

Benthic communities are probably the best biological indicators of disposal impacts because most infaunal species comprising those communities are relatively sedentary. Benthic communities inhabiting sand bottom areas of shallow coastal waters have been examined in the Charleston DMDS (US EPA, 1982; Van Dolah et al., 1983) and at Murrells Inlet (Knott et al., 1983a, 1983b). Limited samples were also collected in the entrance channel to Winyah Bay just outside the

jetties (Hinde et al., 1981). Relatively diverse infaunal assemblages were noted in all areas, with polychaetes generally dominating the communities. Abundant infaunal species in the Charleston DMDS area included the cephalochordate Branchiostoma caribaeum; the sipunculid Aspidosiphon spinalis; the polychaetes Spiophanes bombyx, Goniadides caroliniae, Siphetiboneae, Nephtys picta and Prionospio cristata; the annelidiform brevicoelom Lupuladria doma; the amphipod Rhepoxynius epistomus; and nematodes (Van Dolah et al., 1983). At Murrells Inlet, the abundant subtidal infauna were the polychaetes S. bombyx, Scolecopsis squamata and Podarke obscura; the amphipods Prochaetostomus deichmanniae, Acanthochaetostomus millsi, and Platyschnopidae; the bivalves Tellina sp., Crassinella martinicensis and Donax variabilis; and nematodes (Knott et al., 1983b). In the entrance channel to Georgetown Harbor, the bivalves Mulinia lateralis and Crassinella lunulata and the polychaetes P. cristata and Paraprionospio pinnata were most abundant (Hinde et al., 1981).

Sessile benthic invertebrates commonly found in the Charleston DMDS included the hydroid Clytia cylindrica; the bryozoans Membranipora tenuis, Microsporella ciliata and Parasmittina nitida; and the barnacle Balanus venustus. Most of these sessile species were attached to large shells, and other firm substrata. The bivalve Chama macerophylla and the sand dollar Mellita quinquesperforata were also prevalent in this DMDS, with M. quinquesperforata being most common in finer sediments (Van Dolah et al., 1983).

In the entrance channel to Georgetown Harbor, sand dollars (M. quinquesperforata) were the most abundant large invertebrates collected by dredge, whereas shrimp (Penaeus setiferus, P. aztecus) and blue crabs (Callinectes sapidus) were the most abundant invertebrates caught by trawl (Hinde et al., 1981). Wenner et al. (1981) also found these decapod crustaceans to be numerically dominant in their study of Winyah Bay.

No long-term effects of disposal on benthic communities have been detected in the Charleston DMDS, primarily due to the similarity of dredged material to the existing sediments in the disposal area (Van Dolah et al., 1983). Data on benthic communities present in the Georgetown DMDS were lacking prior to the present study.

Demersal fish communities associated with sand bottom habitat in South Carolina coastal waters have been examined by Wenner and Barans (1980). Dominant species in the 9-18 m depth zone included southern porgy (Stenotomus aculeatus), sea cat (Arius felis), sand perch (Diplectrum formosum), lizard fish (Synodus foetens) and spot (Leiostomus xanthurus). Abundant fishes caught in the Winyah Bay estuarine system by Wenner et al. (1981) and Allen et al. (1982) included Atlantic menhaden (Brevoortia tyrannus), silver perch (Bairdiella chrysura), bay anchovy (Anchoa mitchilli), star drum (Stellifer lanceolatus), weakfish (Cynoscion regalis), spot (L. xanthurus), white catfish

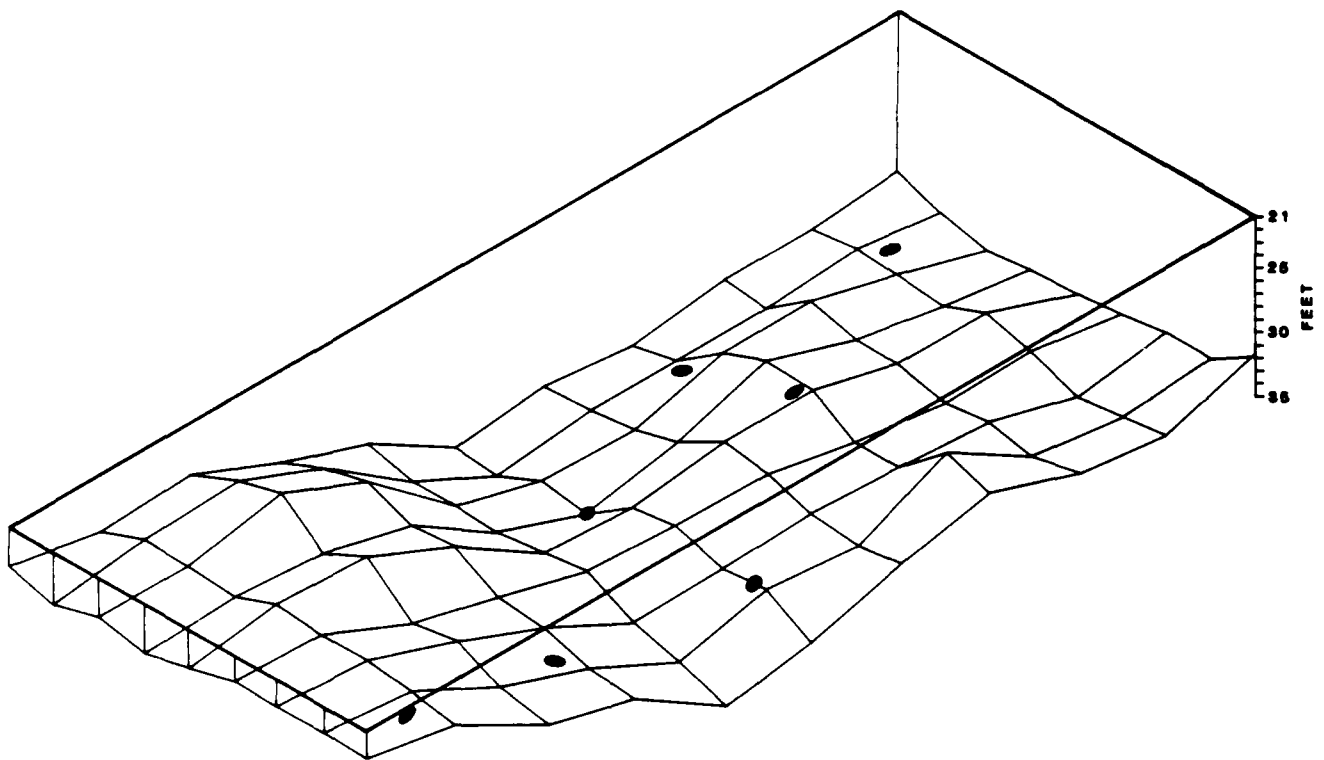


Figure 4. Three-dimensional plot of bottom survey data collected in the Georgetown DMDS by the U.S. Army Corps of Engineers, April 1983. Rectangular boundaries represent the DMDS boundaries and dots represent the stations sampled during winter and summer in the present study. The vertical scale is greatly exaggerated relative to the horizontal scale.

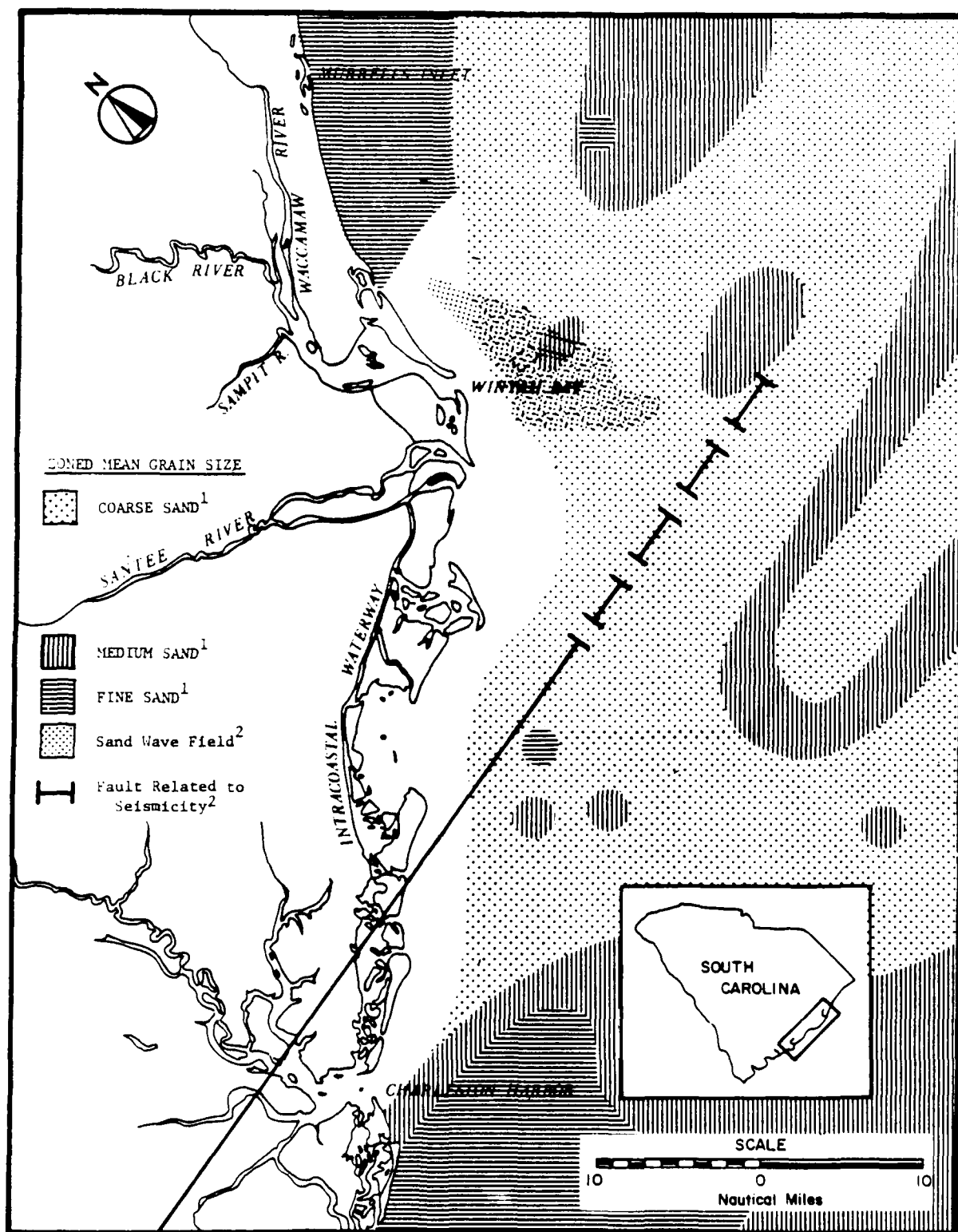


Figure 3. Areal distribution of mean grain size: <sup>1</sup>Pilkey et al., 1979; <sup>2</sup>MMS, 1983.

greatest turbidity would be expected due to suspended sediments. In these bottom samples, turbidities in winter would have been influenced by the high runoff from Winyah Bay, which produced a maximum of 42.0 FTU at station DS03. The highest bottom turbidities in summer (up to 28.0 FTU) may have resulted from the activity of shrimp trawlers in the area during the summer sampling cruise.

Turbidities at the mouths of other South Carolina estuaries have greatly exceeded the maximum value recorded during this study. Mathews and Shealy (1982) and Mathews et al. (1981) reported maxima of 135 FTU at the mouth of Charleston Harbor, 91 FTU at the mouth of the South Santee River, and 84 FTU at the mouth of the North Santee River. Our winter and summer maxima were much lower (42.0 and 28.0 FTU, respectively) and, hence, well within the extremes noted at other nearby sites.

### Currents

Measurements obtained at the 13 offshore stations indicate that water movement in the DMDS, control and "down current" areas is strongly influenced by tidal currents (Figures 9-10). Current velocities ranged from 0.1-0.9 knots during winter and 0.1-1.1 knots during summer sampling periods (Appendix 1). Surface and bottom currents generally flowed in a southerly or south-easterly direction during ebb tides. This suggests that water leaving Winyah Bay is diverted by nearshore currents which generally run in a southerly direction along the coast (Mathews and Pashuk, 1977). Current directions measured near slack-tide periods were more variable and often differed between surface and bottom waters. Generally, flood-tide currents were first detected near the bottom and ebb-tide currents were first observed in surface waters (Appendix 1). During flood tides, the general current direction was towards the north, or towards the Winyah Bay entrance channel. Thus, tidal currents appear to have a stronger influence on waters in the vicinity of the DMDS than nearshore currents. However, the limited current measurements collected during this study were only intended to supplement other hydrographic data and these measurements probably do not adequately define current regimes in the study area.

### Chemistry and Pollutants

Trace metals were generally low in concentration, with many being below the detection limits, e.g. nickel, copper, lead and mercury (Appendix 2 and Table 3). The values reported in this study are generally much lower than values noted by Jones, Edmunds and Associates (JEA) (1979c.) in their study of the Georgetown Harbor channel, but were more similar to the Interstate Electronics Corp. (IEC) results (US EPA, 1982) obtained for the Charleston DMDS (Table 4). Specifically, our cadmium concentrations were higher than the IEC Charleston values (maxima of 7.1 µg/l and 0.493 µg/l, respectively), but much lower than the JEA Georgetown results (up to 150 µg/l). Nickel and lead concentrations measured in the

present study were below the detection limit for each metal, whereas concentrations noted by JEA were as high as 760 µg/l for nickel and 1600 µg/l for lead. Zinc concentrations (minus estimates measured in the control blank sample) were lower than the concentrations noted by JEA, but arsenic concentrations were all higher than those measured by JEA, i.e., 32.4-92.8 µg/l versus < 10.0-30.0 µg/l (Table 4).

A study in Corpus Christi Bay by Holmes et al. (1974) found a seasonal variation in cadmium and zinc concentrations, but their overall results for estimates obtained in winter correlate well with this study. Summer values obtained by Holmes et al. (1974) were much higher due to stagnation within the bay, a condition clearly not present in our study area. Windom (1972) reported copper, lead, cadmium, zinc and mercury concentrations in the Savannah River before, during, and after dredging operations. He noted values of < 1 to 56 µg/l for copper, < 2.0 to 9.8 µg/l for lead, 0.05-0.49 µg/l for cadmium, 11-32 µg/l for zinc, and 0.15-0.21 µg/l for mercury. Our values were comparable, although we noted higher cadmium concentrations and lower lead concentrations (Table 4).

The various PCBs and pesticides listed in Table 4 were below the 50 ppb detection limits listed by Pequegnat et al. (1981) and, hence, they are assumed to be trace amounts. The oil and grease determination however, was positive but not particularly high. Our values ranged from 3.0-4.0 mg/l as compared to the JEA (1979c) range of 20-29 mg/l.

### BOTTOM SEDIMENTS

#### Granulometric Analyses

Bottom sediments at stations sampled in the DMDS consisted of moderately to poorly sorted quartz sand having an average mean grain size of 0.71φ (Table 5, Figure 11). The silt and clay content of the five samples collected from this area was less than 1% (Table 6, Figure 12), suggesting that finer-grained sediments are winnowed out as a result of wave and current activity. Bottom sediments in this region are apparently not below the wave base, thus inhibiting deposition and allowing for removal of fine-grained sediments. The coarse sandy bottom present in the disposal area suggests that any fine-grained sediments previously disposed in the DMDS have been largely dispersed from the study area.

The concentration of calcium carbonate (shell material) varied from 4.66 - 14.97% in the disposal area (Table 7, Figure 13). Station DS03 had the highest concentration of calcium carbonate (14.97%) as a result of the abundance of both whole and fragmented shell material. Some of the shell material present may be from "East Bank" (a large

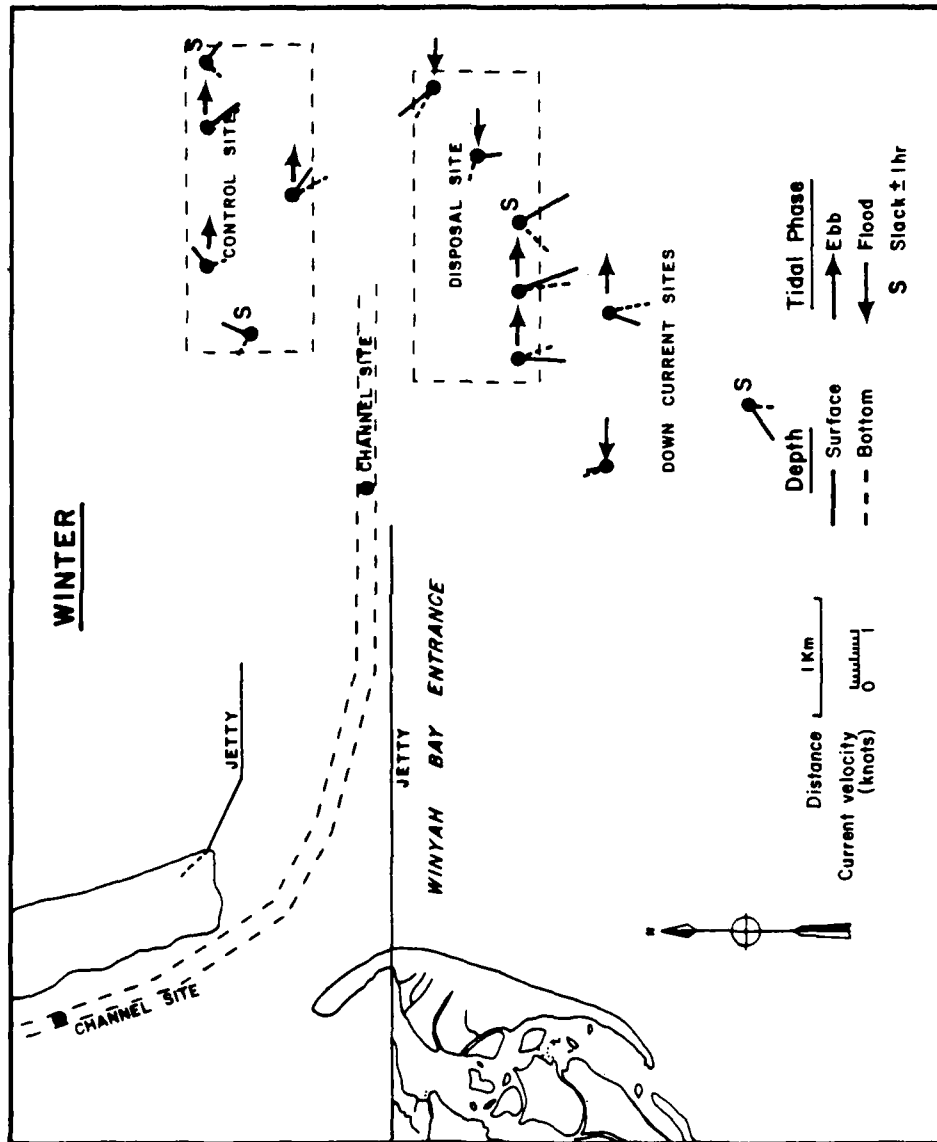


Figure 9. Current velocities and directions for the 13 stations sampled during the winter in and near the Georgetown Harbor DMS.

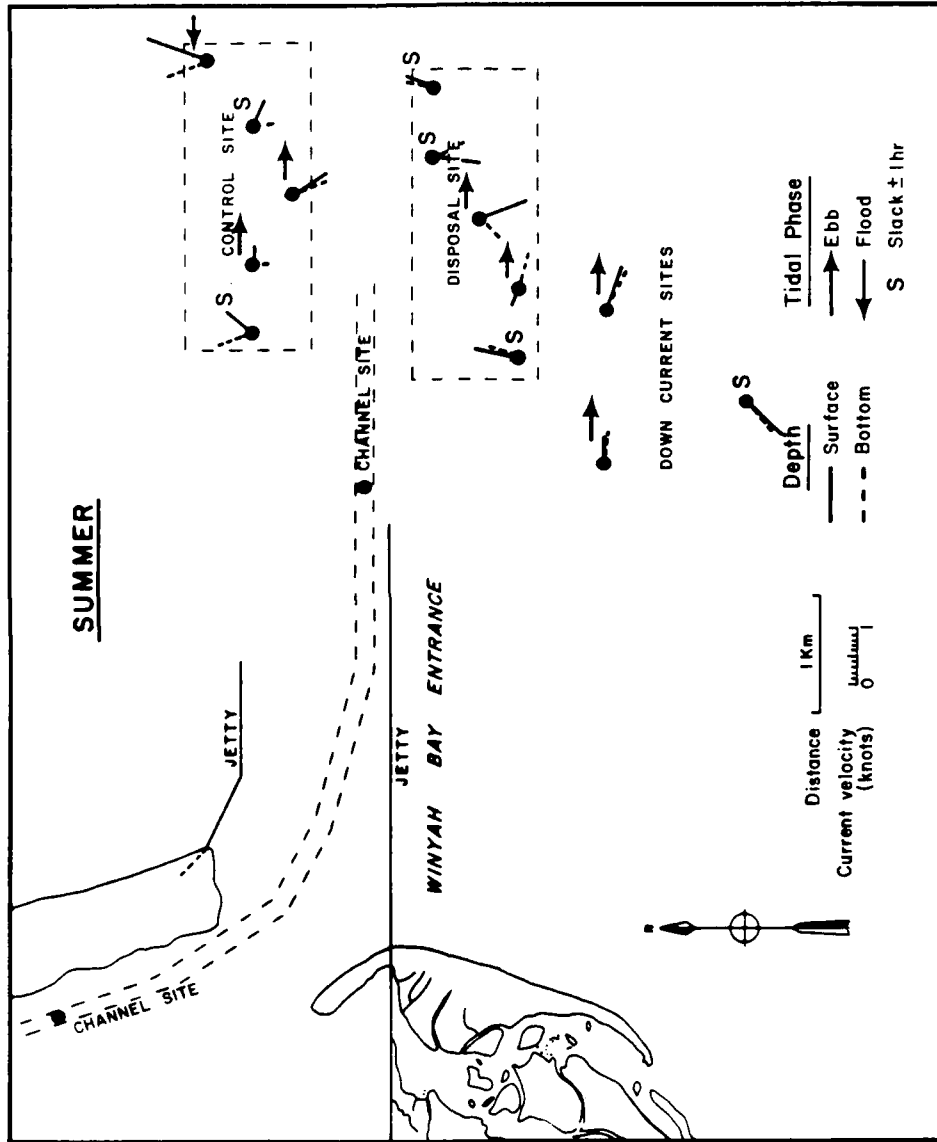


Figure 10. Current velocities and directions for the 13 stations sampled during the summer in and near the Georgetown Harbor DMDS.

Table 3. Maximum concentrations of various substances measured in sediment, water, and tissue samples collected from the vicinity of the Georgetown DMDS.

<u>PARAMETER</u>	<u>SEDIMENT</u>	<u>WATER</u>	<u>TISSUE</u>
Oil and grease	CH02 687 mg/kg	DS,DC 4.0 mg/l	ND
Nitrate as NO <sub>3</sub>	CS13 533.33 mg/kg	NA	ND
Nitrite as NO <sub>2</sub>	CH01 106.28 mg/kg	NA	ND
Total Kjeldahl Nitrogen	DC01 994 mg/kg	NA	ND
Soluble Phosphorus as PO <sub>4</sub>	DS03 1.72 mg/kg	NA	ND
Total Phosphorus as PO <sub>4</sub>	DC01 53.13 mg/kg	NA	ND
Total Organic Carbon	DC01 0.810% mg/g	NA	ND
Cadmium	ND	CS05 7.1 mg/l	ND
Arsenic	CS13 1.47 µg/g	CS05 92.8 mg/l	DS 2.34 mg/g
Chromium	ND	CS05 5.3 mg/l	ND
Nickel	ND	ND	ND
Copper	DC03 4.02 µg/g	ND	DS 9.65 mg/g
Iron	DC03 15,473 µg/g	ND	ND
Lead	ND	ND	ND
Mercury	DS08 0.61 µg/g	ND	ND
Zinc	CH02 41.04 µg/g	CH01 265 mg/l	DS 53.61 mg/g
Pesticides	ND	ND	ND
Total resolved Hydrocarbons	CS02 8.95 µg/g	CH01 416.63 mg/l	ND

ND - Not Detectable

NA - Not Analyzable



Table 4. Comparisons of hydrographic chemical analyses for Georgetown and Charleston Harbor areas.

	G E O R G E T O W N					JEA ** GEORGETOWN HARBOR CHANNEL
	CHANNEL CH01	CONTROL CS05	DISPOSAL DS08	DOWN CURRENT DC02	IEC * ODMDS	
PCBs Aroclor 1254 µg/l	ND	ND	ND	ND	ND	< 1.0
BHC µg/l	ND	ND	ND	ND	ND	< 0.5
lindane µg/l	ND	ND	ND	ND	ND	NA
heptachlor µg/l	ND	ND	ND	ND	ND	< 0.5
DDE µg/l	ND	ND	ND	ND	ND	< 0.5
DDD µg/l	ND	ND	ND	ND	ND	< 0.2
DDT µg/l	ND	ND	ND	ND	ND	< 0.2
chlordane µg/l	ND	ND	ND	ND	ND	< 0.5
dieldrin µg/l	ND	ND	ND	ND	ND	< 0.1
endrin µg/l	ND	ND	ND	ND	ND	< 0.2
mirex µg/l	ND	ND	ND	ND	ND	< 0.3
methoxychlor µg/l	ND	ND	ND	ND	ND	< 1.0
toxaphene µg/l	ND	ND	ND	ND	ND	< 5.0
Oil and Grease µg/l	3.0	3.0	4.0	4.0	NA	20 - 29
Cadmium µg/l	0.8	7.1	1.6	3.4	0.040 - 0.493	110 - 150
Arsenic µg/l	78.6	92.8	41.4	32.4	NA	< 10.0 - 30.0
Chromium µg/l	1.4	5.3	4.7	2.1	NA	< 300
Nickel µg/l	< 5.0	< 5.0	< 5.0	< 5.0	NA	600 - 760
Copper µg/l	< 50	< 50	< 50	< 50	NA	< 100
Lead µg/l	< 1.0	< 1.0	< 1.0	< 1.0	0.032 - 3.20	1100 - 1600
Mercury µg/l	< 0.2	< 0.2	< 0.2	< 0.2	< 0.03 - 0.076	< 0.2
Zinc µg/l	265	150	172	172	NA	140 - 240

\* IEC Interstate Electronics Corp. (IEC) US EPA (1982)

\*\* JEA Jones Edmunds and Associates. (1979c)

NA - Not Analyzed

ND - Not Detected; Detection Limit is 50 ppb.

Table 5. Statistical analysis of the grain size distribution for sediments from the Georgetown DMDS and vicinity. Data presented in  $\phi$  units.

STATIONS	MEAN	MEDIAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS
DS03	0.16	0.90	1.41	-0.56	0.83
DS06	0.91	1.10	0.83	-0.32	1.24
DS08	0.86	1.15	1.05	-0.45	0.94
DS10	0.80	1.10	0.78	-0.50	0.75
DS13	0.84	1.08	0.79	-0.39	1.04
CS02	0.83	1.15	0.83	-0.52	1.20
CS05	0.78	1.15	0.85	-0.58	1.34
CS09	0.60	0.70	1.00	-0.15	1.06
CS11	1.13	0.45	2.52	+0.48	2.12
CS13	0.83	1.08	0.95	-0.36	0.85
DC01	1.89	2.00	0.65	-0.39	1.27
DC02	1.03	1.20	0.85	-0.42	1.81
DC03	4.59	4.60	2.56	+0.05	0.83
CH01	1.58	1.50	0.83	-0.05	1.09
CH02	3.73	3.10	1.88	+0.53	1.02

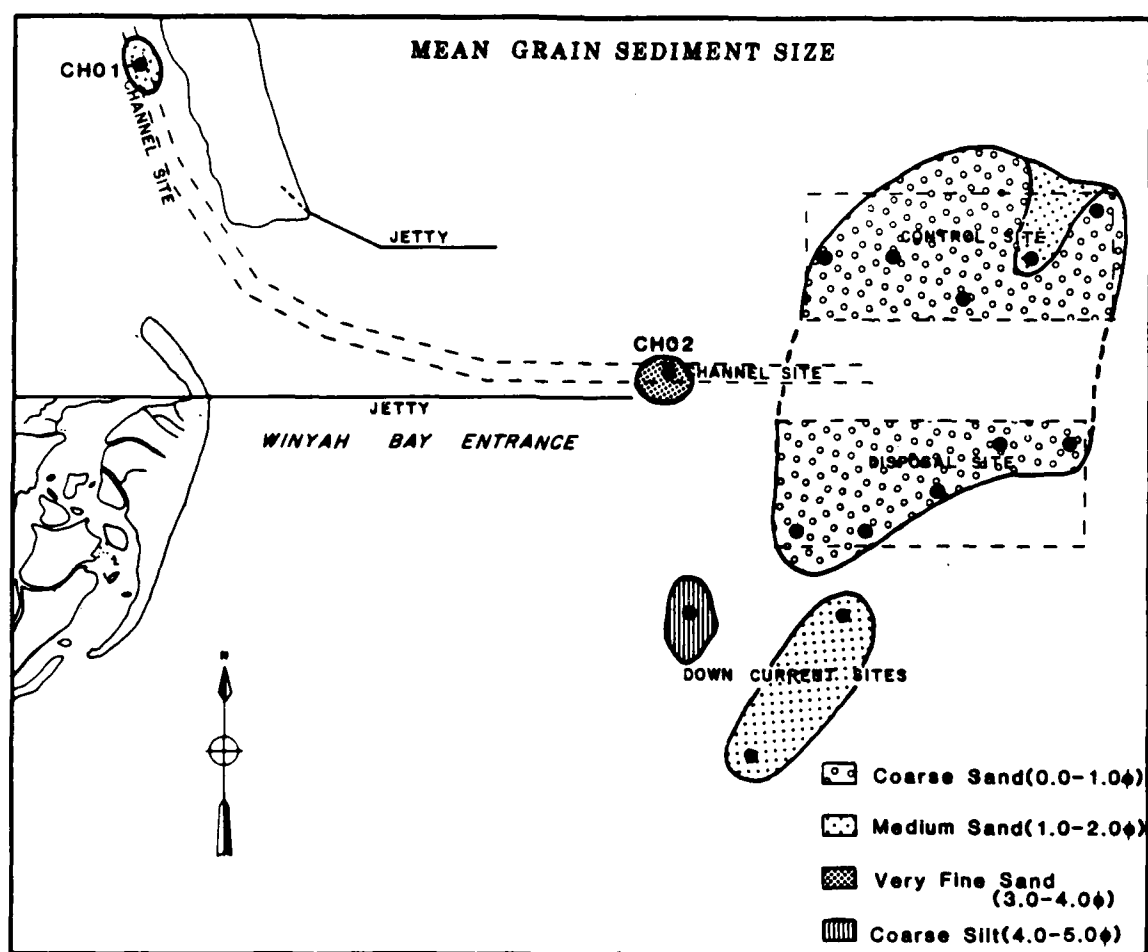


Figure 11. Distribution of mean grain size of sediments collected from the Georgetown DIDS and vicinity.

Table 6. Percentages of sand, silt and clay in sediments from the Georgetown DMDS and vicinity. Estimates represent percent by weight.

STATIONS	SAND	SILT	-	CLAY
DS03	99.74		0.26	
DS06	99.96		0.04	
DS08	99.33		0.67	
DS10	100		trace	
DS13	100		trace	
CS02	99.40		0.60	
CS05	99.98		0.02	
CS09	99.46		0.54	
CS11	83.66	6.42		9.92
CS13	99.85		0.15	
DC01	99.11		0.89	
DC02	99.88		0.12	
DC03	37.89	27.39		34.72
CH01	99.94		0.06	
CH02	54.72	20.09		25.19

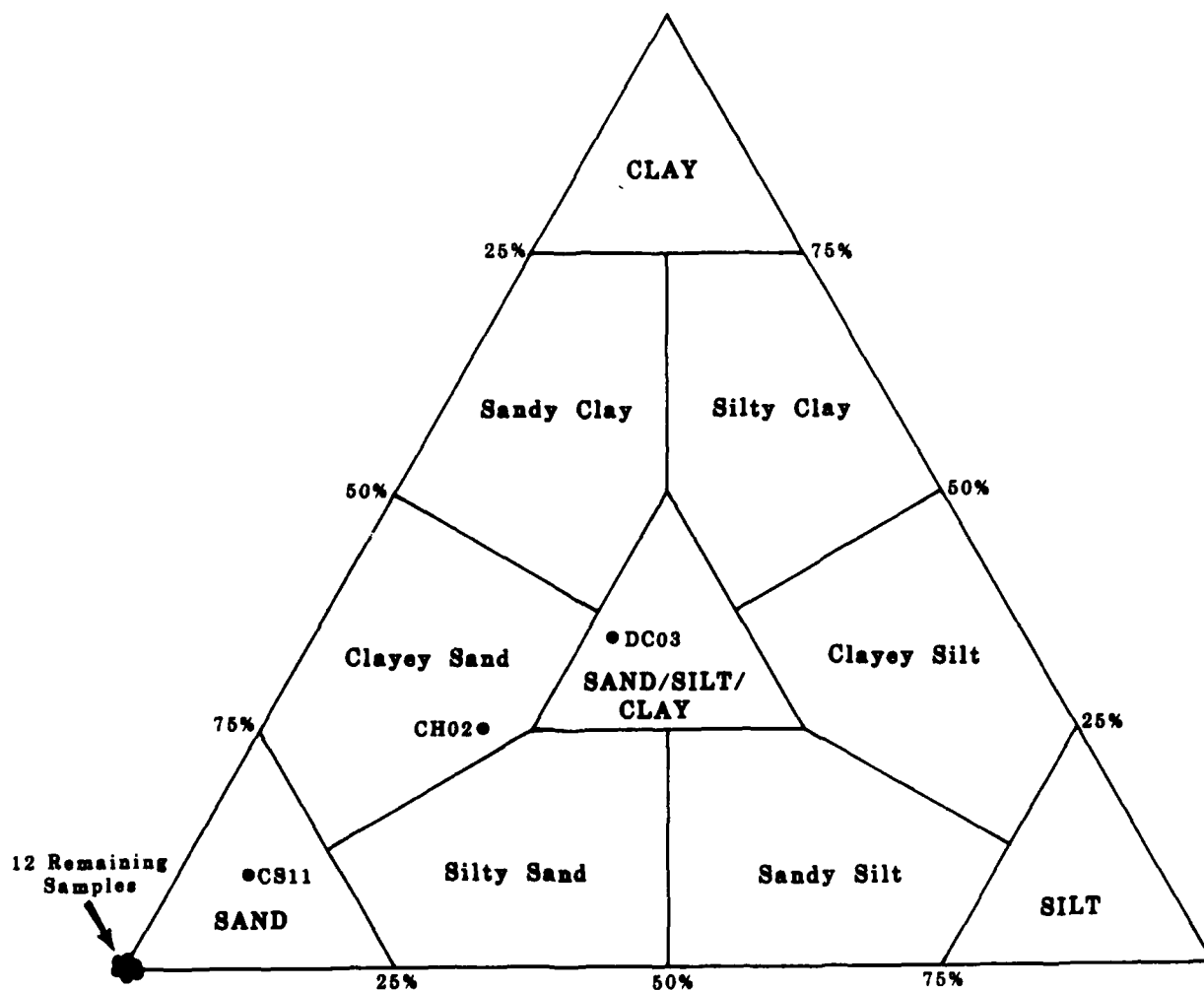


Figure 12. Shepard's classification of sediment types at stations in the Georgetown DIDS and vicinity.

Table 7. Calcium carbonate content of sediments from the Georgetown DMDS and vicinity. Estimates represent percent by weight.

---

<u>STATIONS</u>	<u>CaCO<sub>3</sub></u> <u>(Shell)</u>	<u>QUARTZ</u> <u>(Non-carbonates)</u>
DS03	14.97	85.03
DS06	6.18	93.82
DS08	8.39	91.61
DS10	5.26	94.74
DS13	4.66	95.34
CS02	6.00	94.00
CS05	7.33	92.67
CS09	10.88	89.12
CS11	10.65	89.35
CS13	10.09	89.91
DC01	9.65	90.35
DC02	6.33	93.67
DC03	27.69	72.31
CH01	3.46	96.54
CH02	16.38	83.62

---

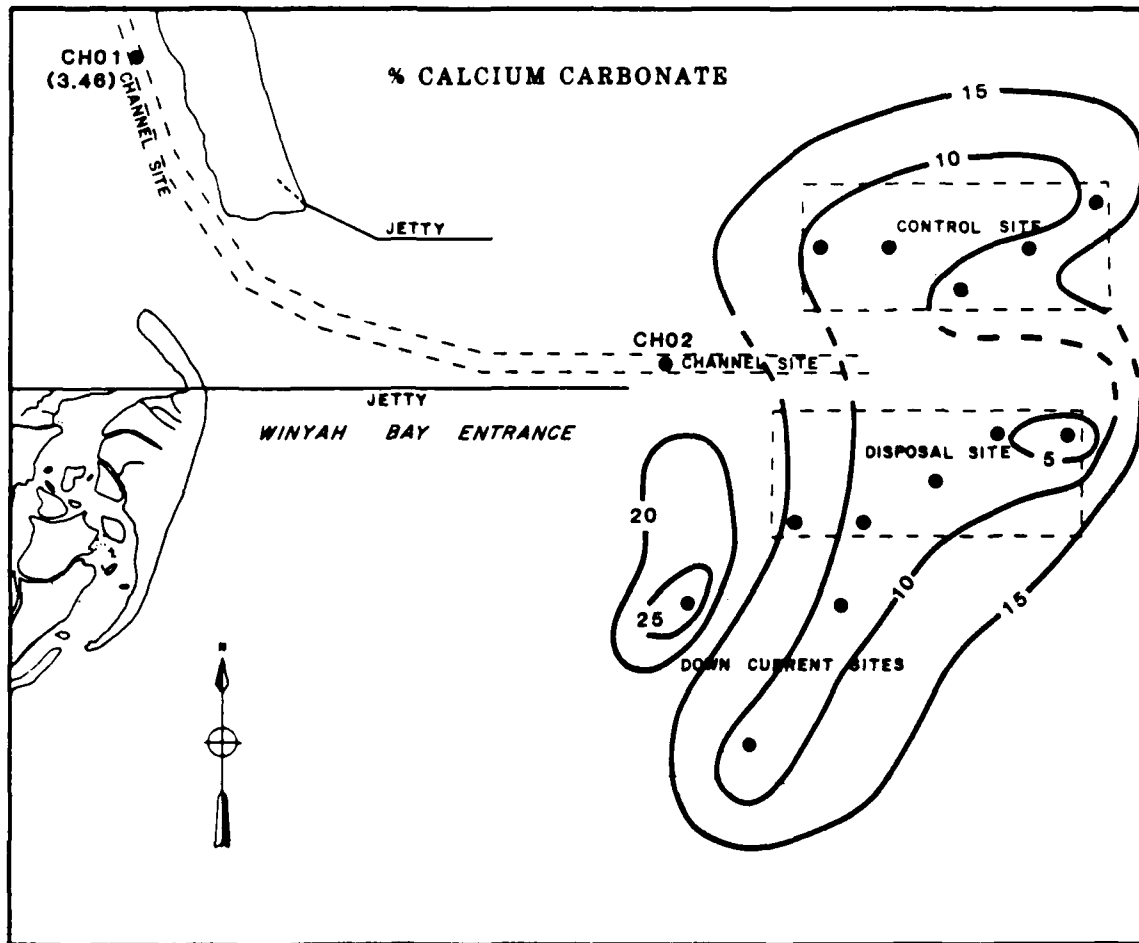


Figure 13. Distribution of percent calcium carbonate content of sediments collected from the Georgetown DMDS and vicinity.

shell bank) located to the west of the DMDS.

Like those at DMDS sites, bottom sediments at control sites consisted primarily of moderately to poorly sorted clean coarse sand having an average mean grain size of 0.830 (Table 5, Figure 11). All of the control site stations, with the exception of station CS11, contained less than 1% by weight of silt and clay (Table 6, Figure 12). Sediments at CS11 consisted of medium sand containing 6.42% silt and 9.92% clay. The average mean grain size of these bottom samples was not significantly different from that of the disposal area ( $P > 0.05$ , ANOVA). Values obtained for the concentration of calcium carbonate (shell material) are, however, slightly higher in the control area (Table 7, Figure 13).

Bottom sediments collected at the "down current" sites differed from sediments found in the DMDS and control areas. Medium quartz sand was present at DC01 and DC02 (Figure 11), and DC03 consisted mostly of a calcareous coarse silt (Tables 5-7, Figures 11-13). The accumulation of this fine-grained shell hash (27.19%  $\text{CaCO}_3$ ) may result from wave abrasion of shell material present on "East Bank". All three samples collected from the "down current" sites were consistently finer-grained than those samples examined from either the control or disposal sites (Table 5), although differences were not statistically significant ( $P > 0.05$ , ANOVA). The decrease in grain size suggests a southerly current dispersal pattern for the sediments in the area.

The two samples collected from the entrance channel leading into Georgetown Harbor differed from sediments collected at most of the offshore stations. Station CH02, located near the seaward extension of the jetties, consisted of poorly sorted clayey sand (Tables 5-7). The high concentration of silt and clay (45.28%) suggests that the channel acts as a settling basin for the deposition of silt and clay. This sample also contained a high concentration (16.38%) of calcium carbonate (Table 7). Station CH01, located further up the bay, consisted of moderately sorted, clean medium sand. Both of these samples suggest that the sediment currently being deposited within the channel is finer-grained than the sediment found within the control or disposal sites located offshore.

Bottom sediments observed by divers showed evidence of wave disturbance at some stations but not at others. Divers also observed wave influence of sediments at stations in the Charleston DMDS which were even deeper than those sampled in the Georgetown DMDS (SCWMRD, 1979). Thus, it is probable that wave disturbance is an important factor influencing bottom sediments in the Georgetown DMDS.

#### Chemistry and Pollutants

Although contaminant concentrations were quite low for most of the water samples collected in this study, they were much higher in the sediments. The higher concentrations measured, however, are not abnormal. The usual sources of

contamination in sediments are the same as those for water pollution, i.e. runoff from urban areas, eolian transport, various industrial sources and occasional spills. Depending upon current regimes, flushing rates, and mixing processes, contaminant loads in the sediments can be insignificant or relatively high. As noted previously, dispersal of suspended sediments near Winyah Bay should be rather widespread, thus precluding the buildup of contaminants in a small geographic area.

Maximum trace metal concentrations measured in this study are presented in Table 3 and Appendix 3. The extreme concentrations are listed in Table 8 for each site and are compared with previous studies in the Charleston DMDS (US EPA, 1982, SCWMRD, 1979). Utilizing the total digestion procedures, our concentration ranges exceeded values noted in the Charleston DMDS for iron, nickel and zinc (Table 8). Highest concentrations of these metals occurred at the channel station CH02. The high iron concentrations may be due to long-term industrial discharges. All trace metal concentrations measured in our study were within (or lower than) the extremes noted by Chen et al. (1976).

Windom (1973) found mercury in marsh sediments along the Savannah River up to 4  $\mu\text{g/g}$ , considerably higher than our maximum of 0.61  $\mu\text{g/g}$ . In addition, Holmes et al. (1974) reported zinc concentrations in Corpus Christi Bay sediments from 6-235  $\mu\text{g/g}$  and cadmium from 0.1-1.9  $\mu\text{g/g}$ . In each case, the maximum concentrations noted far exceeded our maxima, i.e. 235  $\mu\text{g/g}$  versus 41.04  $\mu\text{g/g}$  and 1.9  $\mu\text{g/g}$  versus < 0.1  $\mu\text{g/g}$ . In a 1971 study at Winyah Bay, Johnson (1972) observed sediment concentrations of 48-76  $\mu\text{g/g}$  copper, 92  $\mu\text{g/g}$  zinc, 3,800-4,800  $\mu\text{g/g}$  iron, 8-12  $\mu\text{g/g}$  arsenic, 4.0-16  $\mu\text{g/g}$  lead, 0.063-0.088  $\mu\text{g/g}$  mercury at a station 9-12 miles up river from the mouth. No detectable cadmium or chromium concentrations were noted in that study. Concentrations detected in our study using total digestion were higher for mercury, iron, and chromium; lower for lead, arsenic, copper, and zinc; and similar for cadmium (Appendix 3).

Utilizing data obtained by partial extraction with 0.1 N HCl, we found all metals except lead to be lower in concentration as compared to total digestion (Appendix 3). Partial extraction tends to remove the readily-leached metals from the sediments, which might be available for bioconcentration. Values we observed, based on partial extraction, were generally similar to the concentrations noted in *Busycon carica* tissue (Appendices 3 and 12). Copper and zinc concentrations, however, were higher in the *B. carica* tissue than in the sediments, and the concentration of lead in the sediments at CH02 was higher than that noted in *B. carica*. Bothner et al. (1980) found zinc concentrations virtually identical to ours in sediments from an area southeast of Winyah Bay at mid- to outer-shelf depths.



Table 8. Comparisons of geochemical analyses of sediments for Georgetown and Charleston Harbor areas.

	G E O R G E T O W N				I E C *	S C W M R D **
	CHANNEL	CONTROL	DISPOSAL	DOWN CURRENT	CHARLESTON ODMDS	CHARLESTON HARBOR ODA
PCBs Aroclor 1254 µg/g	ND	ND	ND	ND	0.000492	NA
DDE µg/g	ND	ND	ND	ND	0.000027 - 0.00005	NA
TOC %	0.086 - 0.549	0.047 - 0.529	0.057 - 0.120	0.060 - 0.810	0.05 - 12.5	1.0
Oil and grease mg/kg	< 6 - 687	8 - 206	< 6 - 105	< 10 - 507	9 - 63	< 10 - 22
Nitrate as NO <sub>3</sub> mg/kg	57.97 - 278.57	15.44 - 533.33	17.55 - 32.66	50.77 - 392.0	NA	0.2 - 1.9
Nitrite as NO <sub>2</sub> mg/kg	10.0 - 106.28	0.34 - 8.04	0.21 - 81.31	3.96 - 27.45	NA	0.1 - 0.2
Total Kjeldahl Nitrogen mg/kg	40 - 546	29 - 266	20 - 807	31 - 994	NA	< 100 - < 1000
Soluble Phosphorus as PO <sub>4</sub> mg/kg	1.20 - 1.63	0.231 - 1.01	0.849 - 1.72	0.304 - 1.20	NA	< 0.1 - 2.2
Total Phosphorus as PO <sub>4</sub> mg/kg	8.43 - 34.72	8.11 - 15.44	5.82 - 11.26	5.92 - 53.13	NA	700 - 13800
Cadmium µg/g	< 0.1	< 0.1	< 0.1	< 0.1	NC	< 0.1 - 0.4
Arsenic µg/g	1.38 - 1.44	0.41 - 1.47	.36 - 1.36	1.07 - 1.38	NA	1.1 - 10.0
Chromium µg/g	1.25 - 14.9	< 0.1 - 8.50	1.16 - 2.46	1.22 - 9.05	NA	7.0 - 38.0
Nickel µg/g	< 0.5 - 9.95	< 0.5	< 0.5 - 5.89	< 0.5	NA	< .5 - 7.3
Copper µg/g	< 0.1 - 2.49	< 0.1	< 0.1 - 1.02	< 0.1 - 4.02	NA	8.0 - 27.0
Iron µg/g	5,075 - 15,473	2,175 - 8,308	2,180 - 4,227	3,608 - 11,558	NA	1,800-6,800
Lead µg/g	< 0.5	< 0.5	< 0.5	< 0.5	NC	< 0.5 - 2.5
Mercury µg/g	0.27 - 0.51	0.11 - 0.38	0.08 - 0.61	0.21 - 0.55	0.001 - 0.005	.06 - 1.13
Zinc µg/g	9.60 - 41.04	7.64 - 22.89	5.38 - 11.14	7.83 - 23.77	NA	6.0 - 28.0

\* Interstate Electronics Corp. (US EPA, 1982)

\*\* South Carolina Wildlife and Marine Resources Dept. (1979)

NA - Not Analyzed

ND - Not Detected; Detection Limit is 50 ppb.

NC - Not Comparable; differing analyses.

Their partial leaching technique used as 5.0 N HNO<sub>3</sub> and, hence, resulted in higher concentrations for chromium and copper. Their findings indicated no accumulations of anthropogenic metals in sediments of the continental shelf off South Carolina.

No PCBs or pesticides were detected ( $< 50 \mu\text{g/kg}$ ) in the sediments at any of the stations (Table 3, Appendix 3). Concentrations of DDD, DDE and Dieldrin have been reported as high as 5.2  $\mu\text{g/kg}$ , 3.4  $\mu\text{g/kg}$ , and 9.1  $\mu\text{g/kg}$ , respectively in Winyah Bay sediments (Johnson, 1979). Our results at the mouth and offshore may have been somewhat higher than these, since our detection limit was 50  $\mu\text{g/kg}$ . Chen et al. (1976) reported extremes for both PCBs and pesticides of 0-10  $\mu\text{g/kg}$ . Without finer resolution, we can only conclude that our samples may have been within these limits.

Total organic carbon (TOC) measurements yielded values from 0.47 mg/g at CS05 to 3.10 mg/g at DC01. These extremes coincide with values reported for the Charleston DMDS (Table 3). Oil and grease determinations ranged from a low of 0.2 mg/kg at CH01, DS03, and DS06, to a high of 0.87 mg/kg at CH02. Our maximum at each site greatly exceeded the oil and grease concentrations reported for the Charleston DMDS (Table 3). Our TOC and oil and grease values, however, were relatively low compared to concentrations reported by Chen et al. (1976).

Sediment nutrient concentrations varied considerably between sampling sites (Appendix 3). The maximum nitrate concentrations (533.33 mg/kg) occurred at DS13, while the minimum (15.44 mg/kg) was recorded at CS05. Sediments in the disposal site generally had much lower concentrations of nitrate than the other sites (17.55-32.66 mg/kg). All sampling sites surveyed in this study had much higher nitrate levels than stations sampled in the Charleston DMDS (Table 3). Nitrite was similarly variable with respect to location and much higher than reported in the Charleston DMDS (Table 3).

Total Kjeldahl nitrogen ranged from 20-994 mg/kg with great variability between the sampling sites (Table 3). The overall magnitude of concentrations, however, agreed with values reported for the Charleston DMDS ( $< 100 - 1000 \text{ mg/kg}$ ).

#### BENTHIC COMMUNITY

##### Beam Trawl Collections

Beam trawl collections taken during winter and summer yielded 414 total species, 126 invertebrate taxa, and 18 fish species.

Appendix 4a lists the invertebrates collected, more species of arthropods (14 species) were collected than any other taxonomic group. Groups of lesser importance included cnidarians (21 species), mollusks (10 species), and mollusks (10 species). Together with the arthropods, a combined 145 of the total invertebrate

taxa in beam trawl collections. These groups also accounted for the largest number of species in dredge collections from Winyah Bay (Hinde et al., 1981) and the ocean disposal area near Charleston Harbor (Van Dolah et al., 1983), although the order of their importance differed among the studies.

Decapod crustaceans dominated the three areas sampled during winter and summer in terms of percent contribution of species (Figure 14). Fish were also important at most sites, except for control stations sampled in winter, where bryozoans ranked second to decapod crustaceans in number of species. For all stations combined, bryozoans were more diverse in winter than summer, whereas the number of cnidarian and fish species increased in summer.

Species which occurred in more than half of the 26 collections taken from the three areas sampled were the portunid crabs *Ovalipes stephensoni* and *Portunus gibbesii*; the hydroid *Halecium* sp.; the penaeid shrimp *Trachypenaeus constrictus*; the bryozoan *Membranipora tenuis*; and the sciaenid fish *Leiostomus xanthurus*. Only one of these species, *M. tenuis*, was also frequently encountered by Hinde et al. (1981) and Van Dolah et al. (1983) in faunal surveys of Winyah Bay and the Charleston DMDS, respectively. Seasonal comparisons of the most frequently encountered species in beam trawl collections indicated that only *O. stephensoni*, *P. gibbesii*, *T. constrictus*, and *M. tenuis* were widespread in both winter and summer (Table 9). In addition, more taxa were frequently encountered during summer collections than during winter, suggesting a seasonal change in the occurrence of certain taxa within the three areas sampled.

Seasonality also apparently had an effect on the number of species (s) occurring in the study areas. The median number of species collected in summer (120 total taxa) was significantly greater than in winter (88 total taxa) ( $P < 0.05$ ). This pattern was consistent for each of the three areas sampled and, with only two exceptions (DS03, DC03) was also consistent for sites sampled during both winter and summer (Figure 15). The high number of species observed at DC03 in winter was probably related to the presence of a large quantity of submerged wood, which provided suitable substrate for epifaunal colonization. Submerged substrates such as shell and wood occurred in varying quantities at several stations and no doubt contributed to much of the variation in number of species among stations (Figure 15).

No consistent trends and no statistically significant differences in median s were found among the three sampling areas ( $P > 0.05$ ). However, a comparison of total s among these areas indicated that stations in the control site yielded the most (115) species, whereas "down current" and disposal stations yielded 86 and 95 species, respectively. This is noteworthy in view of the fact that equal



only from samples collected during the summer season. For this reason, their abundance at each site may be somewhat underestimated, although comparisons between sites should be valid, nonetheless.

The relative abundance of different major taxa collected from the Georgetown DMDS was somewhat different than that reported by Van Dolah et al. (1983) for the Charleston DMDS. Off Charleston, polychaetes (37%) were conspicuously more abundant than pelecypods (7%), and cephalopodates (1%) and sipunculids (5%) represented a considerable portion of the total number of organisms.

In the Georgetown DMDS study area, we noted temporal and spatial variation in the dominant species (rank 1 in abundance) (Table 14). The ruderal clam, *Ensis directus*, was the most abundant species at each site during the winter, with more than twice as many specimens collected than the next most abundant species. In summer samples, this dominance by *E. directus* was no longer apparent, and the limulitiform brvozoan *Cupuladria doma* was the most abundant species at disposal and "down current" stations. Nematodes were numerically dominant at control stations. Since *C. doma* was not processed in winter samples, these apparent seasonal changes in dominance may not be real. However, it should be noted that five species—the pelecypods *E. directus*, *Grassinella martinicensis*, and *Grassinella lunulata*; the solitary ascidian *Pyura vittata*; and nematodes—were among the ten most abundant collected during both seasons (Table 14).

Many of the dominant species were widely distributed throughout the study area (Table 14) and none were restricted to a particular site. The disposal and "down current" sites were numerically dominated by one or two species during each season. At the control site, however, there was a more even distribution of individuals among several species.

Two taxa common at the control site, the capitellid polychaete *Mediomastus californiensis* and nematodes, are deposit feeders, while suspension feeding animals were dominant at all other sites (Table 14). In fact, suspension feeders accounted for at least 51% of the total number of animals from the entire study area. The actual percentage may be greater than this, since only known suspension feeders that contributed more than 1% of the total number of organisms were considered.

In contrast to the suspension feeding community observed in the Georgetown DMDS, the SEW-DMDS were characterized as being primarily composed of small-bodied deposit feeders (often polychaetes and crustaceans) (US EPA, 1982). That study also noted that in the Charleston

disposal site, the suspension feeding community accounted for 64% of the total number of individuals. However, the suspension feeding community in the Georgetown DMDS was more diverse, with 11 species contributing 51% of the total number of individuals. The suspension feeding community in the Georgetown DMDS may be more important than the studies indicated (US EPA, 1982).

To evaluate the effect of seasonality on numerical dominance and areal distribution of important species, the mean density of each species which contributed greater than 1% of the total number of individuals was plotted against station location and season (Figure 19). Actual values for each species are listed in Table 15. Appendixes 5-10 indicate a high degree of variability among replicates and stations within each site and season. Similar temporal and spatial variability is common among macrobenthic communities of the South Atlantic Bight (Frankenberg and Leiper, 1977; US EPA, 1982; Knott et al., 1983a).

Three species were conspicuous when compared to the others because they were considerably more abundant. *Ensis directus*, *C. martinicensis*, and *C. doma* were far more numerous than all other species (note the difference in scale of the top row of histograms, Figure 19). The most abundant species, *E. directus*, is a common shallow-water inhabitant along the entire Atlantic Coast (Theroux and Wigley, 1983). It was found in significantly greater numbers at all sites during the winter ( $P < 0.001$ , ANOVA), probably due to spawning activity during this season. Knott et al. (1983a) noted a single spawning of this species sometime between November and February. The reproductive cycle of *E. directus* should be considered in determining the optimal schedule of release of dredged material in this area since Harrison et al. (1964) reported that its larval dispersal and settlement helped to mitigate the effects of defaunation caused by dredging and spoil disposal in the lower Chesapeake Bay.

Mean densities of *E. directus* were not significantly different between sites ( $P > 0.05$ ), nor were significant differences ( $P > 0.05$ ) noted between sites in the mean densities of the second and third most abundant species, *C. martinicensis* and *C. doma*. These species however, both had higher densities in the disposal site than elsewhere (Figure 19). Both of these are typically free-living species found in coarse, shelly sand of shallow coastal waters (Harrv, 1966; Winston, 1982). *Cupuladria doma* was also among the dominant species in the Charleston DMDS (Van Dolah et al., 1983).

Another species of *Grassinella* (*C. lunulata*) was the fourth most abundant species overall.

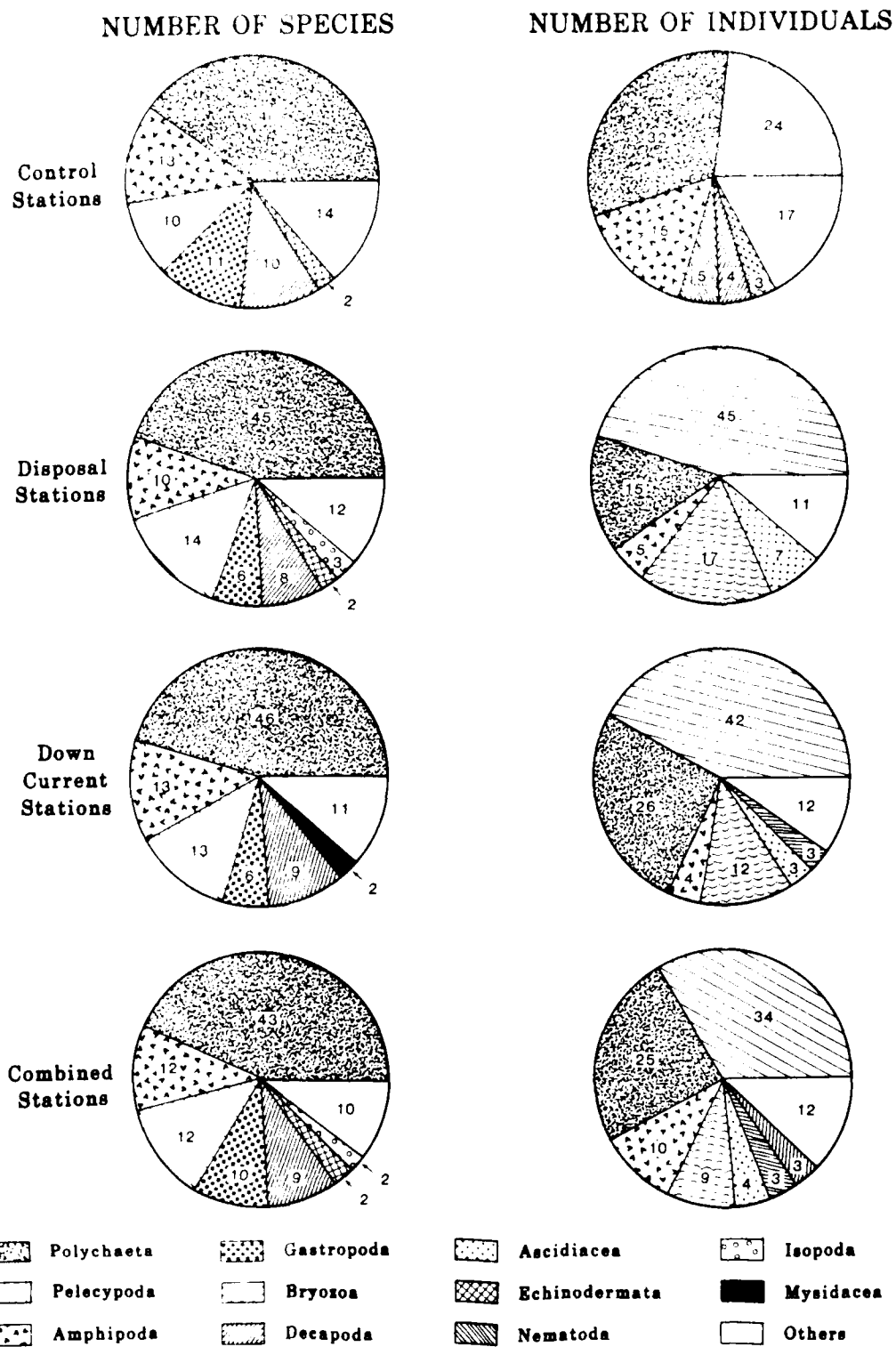


Figure 18. Percentage contribution of major taxa to the number of species and number of individuals in grab samples from control, disposal, and "down current" sites. The number of individuals noted for bryozoans is based on the number of colonies.

Table 13. Number of individuals representing each of the major macroinvertebrate taxa in grab samples from control, disposal, and "down current" sites. (\* = bryozoans were not enumerated in winter samples).

Taxa	CONTROL STATIONS		DISPOSAL STATIONS		DOWN CURRENT STATIONS		COMBINED STATIONS	
	Total Number	Rank	Total Number	Rank	Total Number	Rank	Total Number	Rank
Pelecypoda	2337	2	3197	1	893	1	6427	1
Polychaeta	3159	1	1031	3	550	2	4740	2
Amphipoda	1490	3	330	5	81	4	1901	3
Bryozoa*	204	11	1198	2	247	3	1649	4
Ascidacea	255	8	498	4	64	6	817	5
Nematoda	498	4	88	9	67	5	653	6
Decapoda	421	5	109	7	50	7	580	7
Echinodermata	309	6	76	10	24	11	409	8
Sipunculida	245	9	151	6	10	13	406	9
Nemertinea	271	7	74	11	46	8	391	10
Oligochaeta	196	12	93	8	31	9	320	11
Gastropoda	239	10	27	14	16	12	282	12
Cumacea	113	13	26	15	2	17	141	13
Anthozoa	105	14	10	18	4	16	119	14
Isopoda	23	16	51	12	26	10	100	15
Mysidacea	43	15	47	13	7	14.5	97	16
Turbellaria	18	17	2	21	-	-	20	17
Tanaidacea	-	-	18	16	-	-	18	18
Cephalochordata	3	21	12	17	1	19	16	19
Hemichordata	3	21	3	19	7	14.5	13	20
Ostracoda	7	18	2	21	1	19	10	21
Stomatopoda	5	19	1	23.5	-	-	6	22
Brachiopoda	3	21	2	21	-	-	5	23
Echiurida	2	23.5	-	-	1	19	3	24
Pycnogonida	1	25.5	1	23.5	-	-	2	25.5
Scaphapoda	2	23.5	-	-	-	-	2	25.5
Phoronida	1	25.5	-	-	-	-	1	27
Total	9953		7047		2128		19128	

Table 12. Number of species representing each of the major macroinvertebrate taxa in grab samples from control, disposal, and "down current" sites. (\* indicates a taxon that was probably represented by more species than indicated due to uncertain or incomplete identifications).

Taxa	CONTROL STATIONS		DISPOSAL STATIONS		DOWN CURRENT STATIONS		COMBINED STATIONS	
	Number of Species	Rank	Number of Species	Rank	Number of Species	Rank	Number of Species	Rank
Polychaeta	116	1	94	1	58	1	152	1
Amphipoda	37	2	22	3	16	2.5	42	2.5
Pelecypoda	30	4	30	2	16	2.5	42	2.5
Gastropoda	31	3	12	5	7	5	36	4
Decapoda	29	5	16	4	12	4	33	5
Echinodermata	7	6	5	7	2	7	9	6
Isopoda	4	9.5	6	6	1	16	7	7
Mysidacea	5	7	4	8	3	6	5	8
Sipunculida*	4	8	3	9	1	16	4	9
Cumacea	4	9.5	1	20.5	1	16	4	10
Anthozoa*	3	11	2	11	1	95	3	11
Bryozoa	2	13	3	10	1	16	3	12
Hemichordata*	2	13	1	20.5	1	16	2	13
Scaphapoda	2	13	-	-	-	-	2	14
Nemertina*	1	17	1	14	1	9.5	1	15
Oligochaeta*	1	17	1	14	1	9.5	1	16
Turbellaria*	1	17	1	14	-	-	1	17
Nematoda*	1	17	1	14	1	9.5	1	18
Ostracoda*	1	17	1	14	1	16	1	19
Tanaidacea	-	-	1	20.5	-	-	1	20
Ascidacea	1	23	1	20.5	1	16	1	21
Brachiopoda	1	23	1	20.5	-	-	1	22
Cephalochordata	1	23	1	20.5	1	16	1	23
Stomatopoda	1	23	1	20.5	-	-	1	24
Echiurida	1	23	-	-	1	16	1	25
Pycnogonida	1	23	1	20.5	-	-	1	26
Phoronida	1	23	-	-	-	-	1	27
Total	288		210		127		357	

included the Atlantic croaker, Micropogonias undulatus; the grey trout, Cynoscion regalis; the banded drum, Larimus fasciatus; the cownose ray, Rhinoptera bonasus; the portunid crabs Callinectes similis and Arenaeus cribrarius; the brown shrimp, Penaeus aztecus aztecus; and the brown alga Sargassum natans.

Groups F and G contained species which were generally ubiquitous throughout the study area and, therefore, not faithful to any particular site group. Group F species were most consistently collected during summer at stations in groups 1 and 2. Two species, Prionotus carolinus and Callinectes tricolor, were collected only in summer. Species in Group G were those which were frequently collected at most stations during both seasons. The most frequently encountered species in the study (Ovalipes stephensoni, Portunus gibbesii, Halecium sp., and Trachypenaeus constrictus) occurred in this group. The only species in Group G which was temporally restricted was Brevoortia tyrannus, the Atlantic menhaden, which occurred only in winter.

Groups H and I included infrequently collected species which were not very constant or faithful to any site group. In these groups, the sponge Tenaciella obliqua; the fishes Trinectes maculatus and Raja eglanteria; and the decapods Hexapanopeus angustifrons, Acetes americanus and Persephona mediterranea were collected only in summer, while the horseshoe crab, Limulus polyphemus, and the anemone Epizoanthus americanus were collected only in winter.

Species in groups J and K were highly faithful to stations comprising site groups 1 and 2, respectively; however, they were not consistently collected at those stations. These two groups constitute a summer assemblage of organisms in the study area, with all members except the flounder Ancylopsetta quadrocellata and the bryozoans Microporella ciliata and Tryptostega venusta occurring exclusively in summer collections.

In conclusion, the community structure of fishes and epifaunal invertebrates in the study area is influenced by seasonality. The number of species was significantly higher in summer. Furthermore, species assemblages differed noticeably between winter and summer, with several species occurring during only one season. Although the total number of species was lowest in the disposal area, comparisons of species composition between sites indicated that lower diversity resulted from fewer sessile organisms, mainly bryozoans and cnidarians. This suggests that less substrate was available for colonization by sessile organisms in the sampled portions of the disposal area. However, lesser amounts of substrate such as wood and shell in the DMDS are probably not related to past disposal activities.

#### Grab Collections

Grab samples from control, disposal, and "down current" stations yielded more than 19,000 individuals representing at least 357 species of invertebrates (Tables 12, 13; Appendices 5-10). More species and individuals were collected from the control site than from disposal or "down current" stations (Tables 12 and 13). Collections from "down current" stations yielded considerably fewer species and individuals than control or disposal sites, but this reflects, in part, the reduced sampling effort in that area (three stations versus five at CS and DS areas).

The number of species collected during the present study was considerably higher than that collected for the Savannah, Charleston, and Wilmington DMDS study (SCW-DMDS; US EPA, 1982). In that relatively limited survey, only 28, 82 and 30 species were found in and adjacent to those disposal areas, respectively. However, a more intensive study of the Charleston DMDS (Van Dolah et al., 1983) reported the occurrence of 439 species, indicating that diversity in sand bottom habitats of South Carolina coastal waters may typically be much higher than previously reported. Knott et al. (1983b) also reported collecting a large number of species (205) in shallower water off the beaches near Murrells Inlet, South Carolina.

Overall, polychaetes were the most well represented group of the 27 higher taxa identified, with 152 species accounting for 43% of the total number of species (Table 12, Figure 18). Polychaetes also accounted for a similar proportion of the number of species within each of the sites sampled (control, disposal, and "down current"). Amphipods, pelecypods (42 species each), gastropods (36 species), and decapods (33 species) were the other diverse taxa and together with the polychaetes comprised about 85% of the total number of species. Only minor differences occurred between control, disposal and "down current" sites with respect to the proportional contribution of these major taxa (Figure 18). The relative importance of these taxonomic groups was also very similar to that observed in the Charleston DMDS, where polychaetes contributed 43% and the same five dominant taxa contributed 82% of the total number of species (Van Dolah et al., 1983).

In terms of numerical abundance, pelecypods were dominant when all stations were considered together (34%). Pelecypods were also the most abundant organisms at disposal and "down current" stations (Table 13, Figure 18). At control stations, however, pelecypods ranked second to polychaetes, and amphipods were relatively more important than at the other sites. Additionally, the relative abundance of lunulitiform bryozoan colonies noted at disposal and "down current" stations was not apparent within the control site. It should be noted that these bryozoans were sorted and identified



## BEAM TRAWL NODAL DIAGRAMS

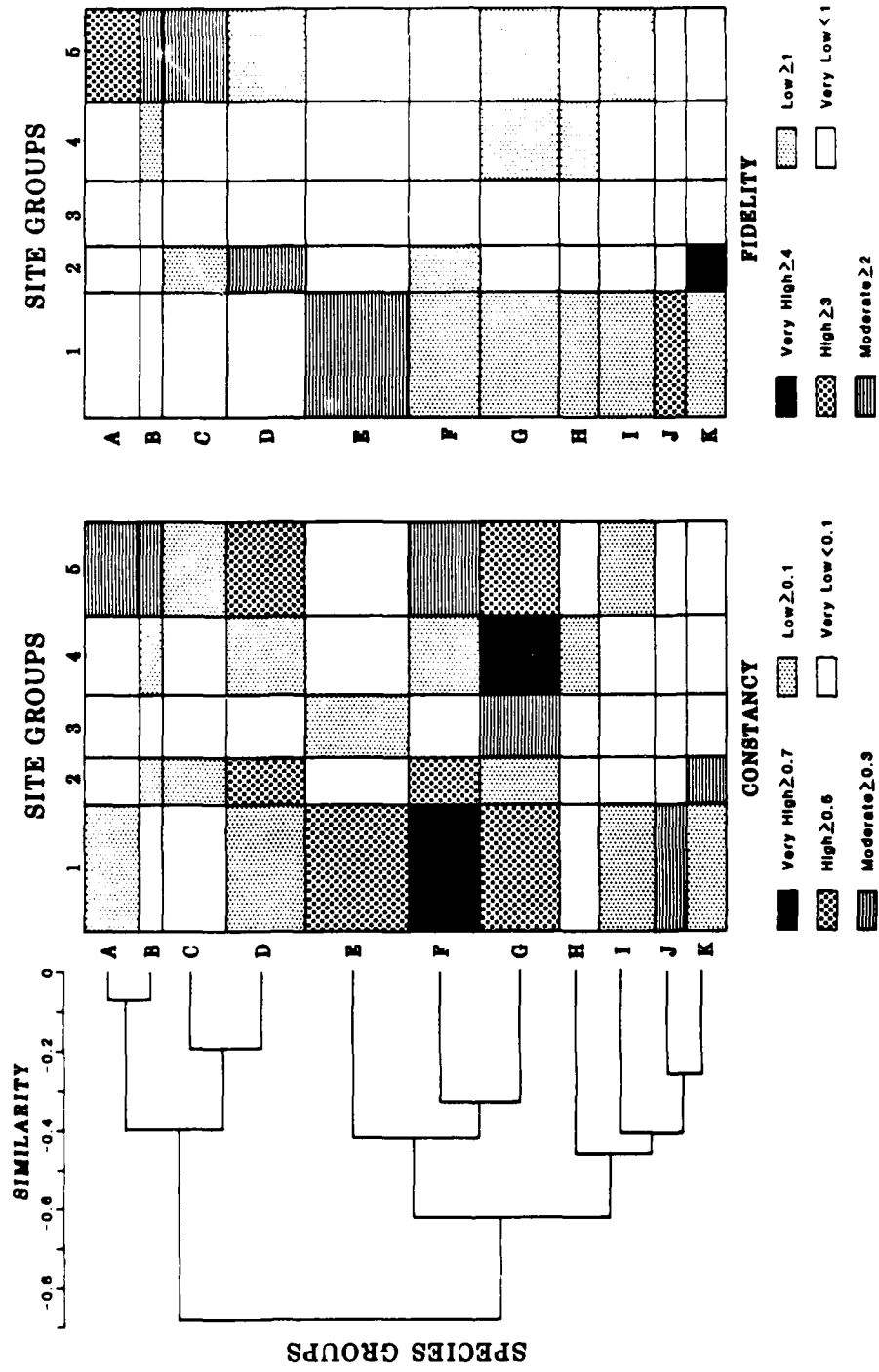


Figure 17. Inverse classification hierarchies and nodal diagram showing constancy and fidelity of station - species group coincidence based on beam trawl collections.

Table 11. Species groups resulting from numerical classification of data from samples collected by beam trawl. (Al = Algae; Ar = Arthropoda; Bry = Bryozoa; Ch = Chordata; Cn = Cnidaria; Ech = Echinodermata; Mo = Mollusca; Po = Porifera).

## Group A

Pilumnus sayi (Ar)  
Telesto fruticulosa (Cn)  
Actiniaria A (Cn)  
Asterias forbesii (Ech)  
Squilla empusa (Ar)  
Urophycis regius (Ch)  
Busycon carica (Mo)

## Group B

Cancer irroratus (Ar)  
Neopanope sayi (Ar)  
Aplidium constellatum (Ch)

## Group C

Hippoporina contracta (Bry)  
Hippaliosina rostrigera (Bry)  
Centropristis striata (Ch)  
Lytechinus variegatus (Ech)  
Asteroidea A (Ech)  
Arbacia punctulata (Ech)  
Astropecten duplicatus (Ech)  
Busycon canaliculata (Mo)

## Group D

Reptadeonella hastingssae (Bry)  
Parasmittina nitida (Bry)  
Portunus spinimanus (Ar)  
Membranipora tenuis (Bry)  
Astrangia astreiformis (Cn)  
Etropus crossotus (Ch)  
Schizoporella errata (Bry)  
Hippoporina verrilli (Bry)  
Chama macerophylla (Mo)  
Electra monostachys (Bry)

## Group E

Micropogonias undulatus (Ch)  
Arenaeus cribrarius (Ar)  
Pagurus longicarpus (Ar)  
Cynoscion regalis (Ch)  
Callinectes similis (Ar)  
Hepatus epheliticus (Ar)  
Larimus fasciatus (Ch)  
Penaeus aztecus (Ar)  
Stellifer lanceolatus (Ch)  
Sclerodactyla briareus (Ech)  
Sargassum natans (Al)  
Aplidium sp. (Ch)  
Rhinoptera bonasus (Ch)

## Group F

Mellita quinquesperforata (Ech)  
Prionotus carolinus (Ch)  
Pagurus pollicaris (Ar)  
Membranipora arborescens (Bry)  
Balanus venustus (Ar)  
Crepidula plana (Mo)  
Calliactis tricolor (Cn)  
Crepidula fornicata (Mo)  
Leiostomus xanthurus (Ch)

## Group G

Symphurus plagiosa (Ch)  
Ovalipes ocellatus (Ar)  
Scophthalmus aquosus (Ch)  
Brevoortia tyrannus (Ch)  
Anchoa mitchilli (Ch)  
Ovalipes stephensoni (Ar)  
Portunus gibbesii (Ar)  
Trachypenaeus constrictus (Ar)  
Libinia emarginata (Ar)  
Halecium sp. (Cn)

## Group H

Tenaciella obliqua (Po)  
Trinectes maculatus (Ch)  
Ascidacea A (Ch)  
Limulus polyphemus (Ar)  
Epizoanthus americanus (Cn)

## Group I

Raja eglanteris (Ch)  
Hexapanopeus angustifrons (Ar)  
Acetes americanus (Ar)  
Persephona mediterranea (Ar)  
Citharichthys macrops (Ch)  
Callinectes sapidus (Ar)  
Porcellana sayana (Ar)

## Group J

Lolliguncula brevis (Mo)  
Hydractinia echinata (Cn)  
Penaeus setiferus (Ar)  
Menippe mercenaria (Ar)

## Group K

Microporella ciliata (Bry)  
Polinices duplicatus (Mo)  
Ancylopsetta quadrocellata (Ch)  
Trypseta venusta (Bry)  
Eupleura caudata (Mo)

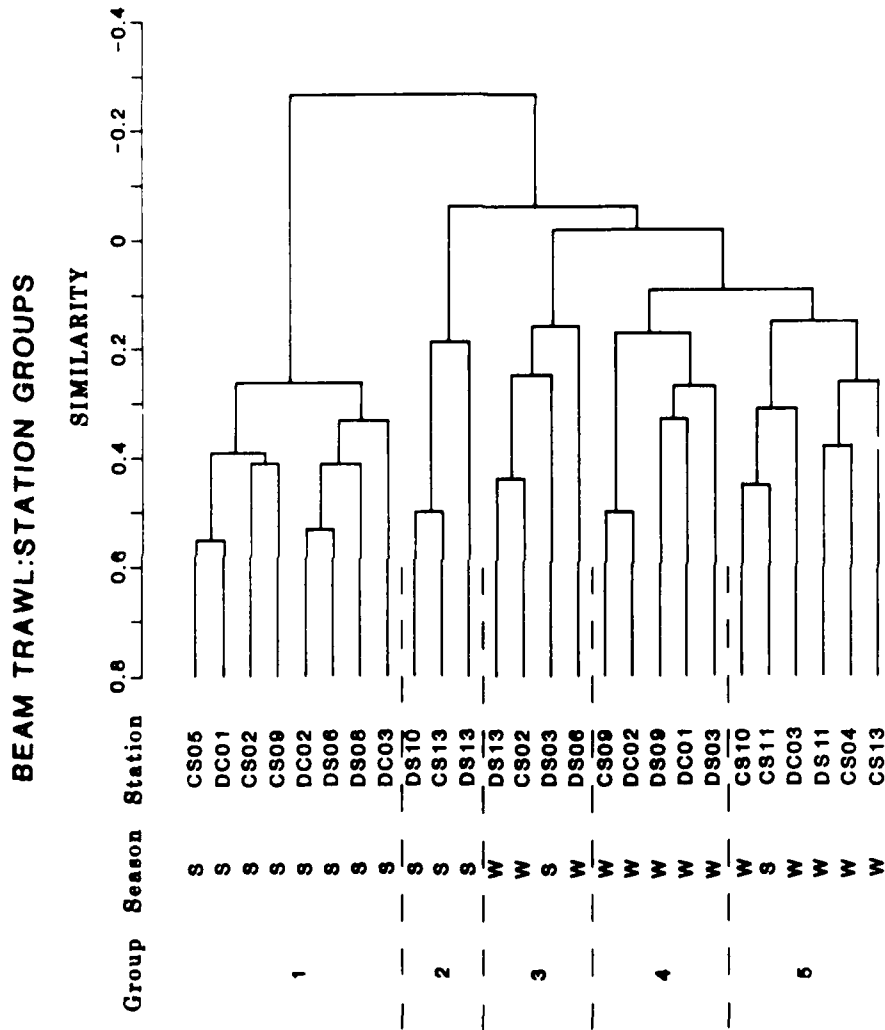


Figure 16. Normal cluster dendrogram showing station groups formed using the Jaccard similarity coefficient and flexible sorting of beam trawl collections.

Table 10. Summary of biomass (kg) for organisms collected with the beam trawl.

	<u>Winter</u>	<u>Summer</u>
Control Stations	$\bar{x} = 1.26$	$\bar{x} = 2.87$
	$S_{\bar{x}} = 0.54$	$S_{\bar{x}} = 0.51$
	$n = 5$	$n = 5$
Disposal Stations	$\bar{x} = 1.844$	$\bar{x} = 1.38$
	$S_{\bar{x}} = 0.64$	$S_{\bar{x}} = 0.58$
	$n = 5$	$n = 5$
Down-Current Stations	$\bar{x} = 1.13$	$\bar{x} = 3.93$
	$S_{\bar{x}} = 0.61$	$S_{\bar{x}} = 1.52$
	$n = 3$	$n = 3$

numbers of tows were made in the disposal and control areas, whereas the "down current" area was sampled less frequently. These data suggest that the diversity of invertebrates and fishes collected by trawl was lower in the disposal area. Van Dolah et al. (1983) also found fewer species in the disposal area near Charleston Harbor, but attributed the lower total number of invertebrate species there to the smaller number of stations sampled rather than to any disposal effects. Examination of species lists from the present study (Appendix 4) indicated that a greater number of bryozoans and cnidarians were present in collections from control and "down current" sites than in the DMDS. The increased number of these sessile taxa is probably related to the patchy occurrence of hard substrate, primarily shell and wood, suitable for colonization at those sites. There was no evidence of extensive hard bottom at any of the sites, and consequently, the total number of invertebrate taxa (126 species) was considerably lower than that reported for hard bottom areas farther offshore in the South Atlantic Bight (Wenner et al., 1983). Values of  $\bar{s}$ , however, were comparable to those reported by Hinde et al. (1981) and Van Dolah et al. (1983). On the other hand, the number of fishes collected (28 species) was much lower than previously reported for Winyah Bay (Wenner et al., 1981; Hinde et al., 1981; Allen et al., 1982) or the nearshore coastal region of the South Atlantic Bight (C. Wenner, pers. comm.). The low number of fish species in beam trawl collections probably resulted from their ability to avoid the sampling gear. The narrow mouth opening, slow-towing speed, and small area swept by the beam trawl makes it an inefficient method of collecting fish, many of which are found higher in the water column or can outswim this gear.

Comparisons of mean biomass between areas and seasons revealed no significant difference for either factor ( $F_{\text{season}[1,2]} = 2.205$ ,  $F_{\text{area}[2,2]} = 0.401$ ;  $P > 0.05$ ) (Table 10). Based on 3-m mouth spread and a tow distance of 500 m, the area swept by the beam trawl was calculated to be 0.15 hectare/tow. Total biomass estimates (kg/ha) for the areas sampled during our study area were:

	winter	summer
Control Stations	8.4	19.1
Disposal Stations	12.3	9.2
"Down Current" Stations	7.5	26.2

Wenner et al. (1981) obtained lower values for biomass of decapod crustaceans and fishes in the Winyah Bay system. However, Hoese (1973) reported values of 10.7 kg/ha for fishes and 6.1 kg/ha for invertebrates in Doboy Sound, Georgia. In the nearshore and coastal habitat of the South Atlantic Bight, biomass estimates for fishes of 23 kg/ha have been obtained in winter and 12 kg/ha in summer

(C. Wenner, pers. comm.). Undoubtedly, higher estimates of total biomass would have been obtained if a sampling gear which was more effective in capturing fish had been used.

Normal cluster analysis of data resulting from beam trawl collections identified five distinct site groups based on similarity of faunal composition (Figure 16). There was no tendency for stations to be grouped according to area since all groups contained stations located both inside and outside the disposal area boundaries. However, stations were grouped by season indicating that species composition in the study area was different between winter and summer.

Inverse cluster analysis of the 81 species which occurred in two or more collections produced 11 groups (Table 11). Nodal diagrams were used to describe the distribution of species in terms of their relative constancy and fidelity to site groups (Figure 17). As indicated by nodal analysis, species in group A were highly restricted but only moderately constant at stations in site group 5, which were sampled primarily in winter (with the exception of CS11). Species in this group are common inhabitants of the nearshore coastal habitat, but are apparently restricted in their distribution. For example, *Busycon carica*, the species chosen for pollutant-uptake assessment, was collected at only two stations, CS05 and DC03. The spotted hake, *Urophycis regius*, was limited in both its spatial and temporal distribution, being collected only at "down current" stations in winter (Appendix 4).

Group B included three species which were neither consistently collected nor restricted to stations in any site group. The rock crab, *Cancer irroratus*, which is a common inhabitant of coastal waters off the New England and Middle Atlantic states (Williams, 1965) was collected only during winter sampling.

Species in Group C were also neither very constant nor faithful to stations in any site group; however, every species in this group except *Busycon canaliculata* was collected exclusively in the control area. Two species in this group, the bryozoan *Hippaliosina rostrigera* and the starfish *Asteroidea A*, were collected only in summer.

Group D is comprised of species which were fairly ubiquitous throughout the study area but were consistently collected only at stations in groups 2 and 5. These species were also well represented in collections from both seasons, with *Chama macerophylla* being the only species which occurred solely in summer (Appendix 4).

Group E contained species which are common inhabitants of the nearshore coastal habitat in the South Atlantic Bight. These species were most consistently collected during summer at stations in group 1. Those species which were collected exclusively during summer

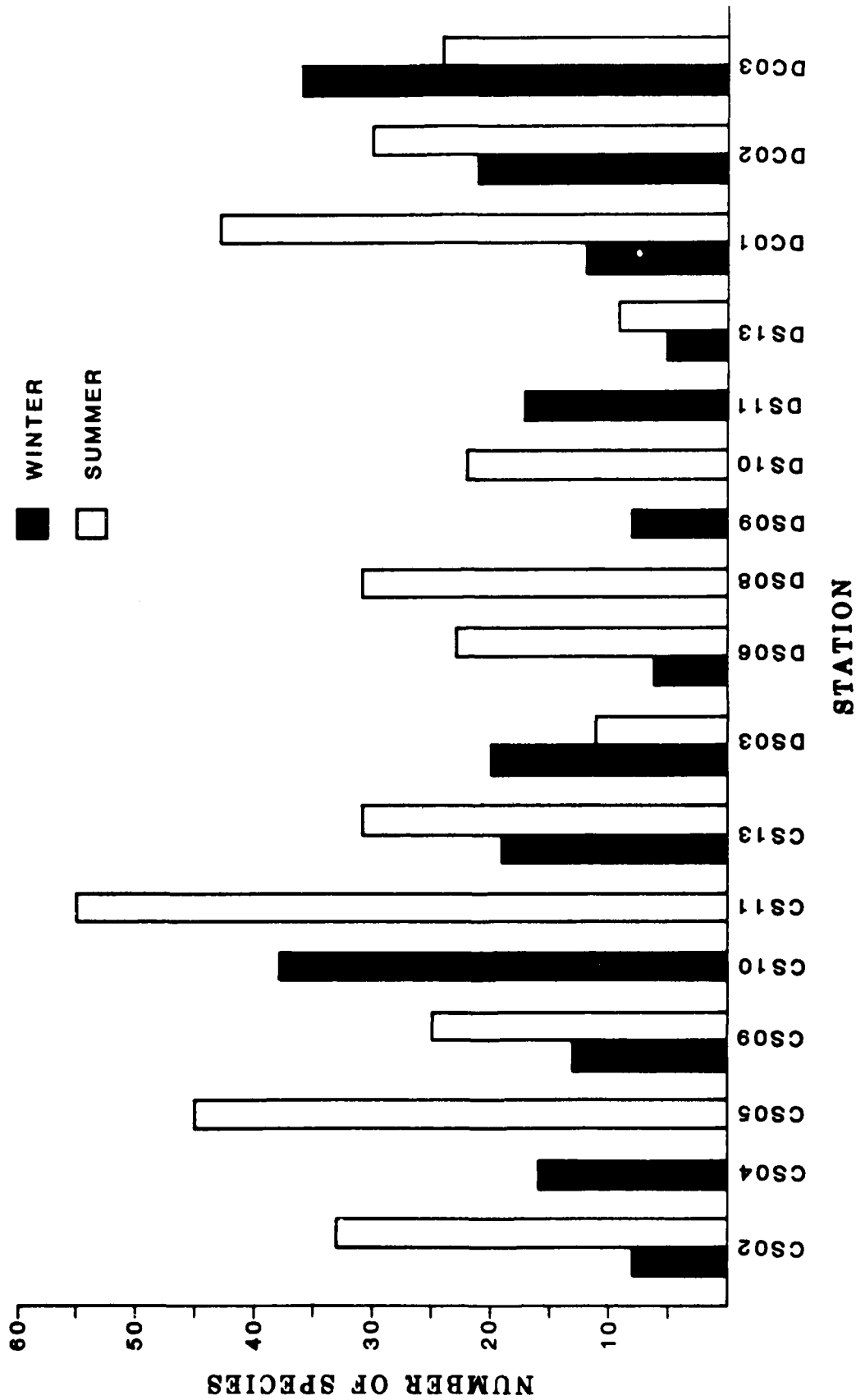


Figure 15. Number of species collected at each station by beam trawl. Stations which were sampled during only one season are represented by a single bar.

Table 9. Species ranked according to their frequency of occurrence (F) in > 50% of beam trawl collections. (Cn = Cnidaria, Ch = Chordata, Ar = Arthropoda, Bry = Bryozoa, Ech = Echinodermata, Mo = Mollusca, Po = Porifera, Al = Algae).

CONTROL STATIONS	F	DISPOSAL STATIONS	F	DOWN-CURRENT STATIONS	F	COMBINED STATIONS	F
WINTER							
Halecium sp. (Cn)	5	Ovalipes stephensoni (Ar)	5	Brevortia tyrannus (Ch)	3	Ovalipes stephensoni (Ar)	12
Brevortia tyrannus (Ch)	4	Portunus gibbesii (Ar)	4	Anchoa mitchilli (Ch)	3	Portunus gibbesii (Ar)	11
Ovalipes stephensoni (Ar)	4	Brevortia tyrannus (Ch)	3	Ovalipes stephensoni (Ar)	3	Halecium sp. (Cn)	11
Portunus gibbesii (Ar)	4	Trachypenaeus constrictus (Ar)	3	Ovalipes ocellatus (Ar)	3	Brevortia tyrannus (Ch)	10
Membranipora tenuis (Bry)	4	Halecium sp. (Cn)	3	Portunus gibbesii (Ar)	3	Trachypenaeus constrictus (Ar)	8
Paracmittina nitida (Bry)	4			Halecium sp. (Cn)	3	Libinia emarginata (Ar)	7
Trachypenaeus constrictus (Ar)	3			Ectopycis regius (Ch)	2	Membranipora tenuis (Bry)	7
Pagurus pollicaris (Ar)	3			Etropus crossotus (Ch)	2		
Libinia emarginata (Ar)	3			Scopthalmus aquosus (Ch)	2		
Asterias forbesii (Ech)	3			Symphurus plaguosa (Ch)	2		
				Trachypenaeus constrictus (Ar)	2		
				Libinia emarginata (Ar)	2		
				Membranipora tenuis (Bry)	2		
SUMMER							
Pagurus pollicaris (Ar)	5	Ovalipes stephensoni (Ar)	5	Microgonias undulatus (Ch)	3	Ovalipes stephensoni (Ar)	13
Ovalipes stephensoni (Ar)	5	Prionotus carolinus (Ch)	4	Prionotus carolinus (Ch)	3	Portunus gibbesii (Ar)	11
Callinectes tricolor (Cn)	5	Portunus gibbesii (Ar)	4	Scopthalmus aquosus (Ch)	3	Prionotus carolinus (Ch)	10
Crepidula plana (Mo)	5	Cynoscion regalis (Ch)	3	Penaeus aztecus aztecus (Ar)	3	Pagurus pollicaris (Ar)	10
Crepidula fornicata (Ch)	4	Leostomus xanthurus (Ch)	3	Pagurus longicarpus (Ar)	3	Mellita quinquesperforata (Ech)	10
Leostomus xanthurus (Ch)	4	Trachypenaeus constrictus (Ar)	3	Pagurus pollicaris (Ar)	3	Leostomus xanthurus (Ch)	9
Hepatus epheliticus (Ar)	4	Callinectes similis (Ar)	3	Ovalipes stephensoni (Ar)	3	Balanus venustus (Ar)	9
Portunus gibbesii (Ar)	4	Halecium sp. (Cn)	3	Portunus gibbesii (Ar)	3	Membranipora arborescens (Bry)	9
Balanus venustus (Ar)	4	Mellita quinquesperforata (Ech)	3	Balanus venustus (Ar)	3	Crepidula fornicata (Mo)	9
Astropecten duplicatus (Ech)	4	Membranipora tenuis (Bry)	3	Mellita quinquesperforata (Ech)	3	Scopthalmus aquosus (Ch)	8
Mellita quinquesperforata (Ech)	4			Membranipora arborescens (Bry)	3	Hepatus epheliticus (Ar)	8
Membranipora tenuis (Bry)	4			Crepidula fornicata (Ar)	3	Callinectes tricolor (Cn)	8
Prionotus carolinus (Ch)	3			Raja eglanteria (Ch)	2	Membranipora tenuis (Bry)	8
Scopthalmus aquosus (Ch)	3			Larimus fasciatus (Ch)	2	Crepidula plana (Mo)	8
Symphurus plaguosa (Ch)	3			Stellifer lanceolatus (Ch)	2	Microgonias undulatus (Ch)	7
Ovalipes ocellatus (Ar)	3			Symphurus plaguosa (Ch)	2	Penaeus aztecus aztecus (Ar)	7
Portunus spinimanus (Ar)	3			Tenacella obliqua (Po)	2	Trachypenaeus constrictus (Ar)	7
Callinectes sapidus (Ar)	3			Trachypenaeus constrictus (Ar)	2	Pagurus longicarpus (Ar)	7
Squilla empusa (Ar)	3			Hepatus epheliticus (Ar)	2	Ovalipes ocellatus (Ar)	7
Hydractinia echinata (Cn)	3			Ovalipes ocellatus (Ar)	2	Lolliguncula brevis (Mo)	7
Astrangiaastreiformis (Cn)	3			Arenaeus cribrarius (Ar)	2		
Arbacia punctulata (Ech)	3			Leostomus xanthurus (Ch)	2		
Paracmittina nitida (Mo)	3			Callinectes sp. (Ar)	2		
Reptadeonella hastingsae (Mo)	3			Callinectes tricolor (Cn)	2		
Lolliguncula brevis (Mo)	3			Crepidula plana (Mo)	2		
				Lolliguncula brevis (Mo)	2		
				Sargassum natans (Al)	2		

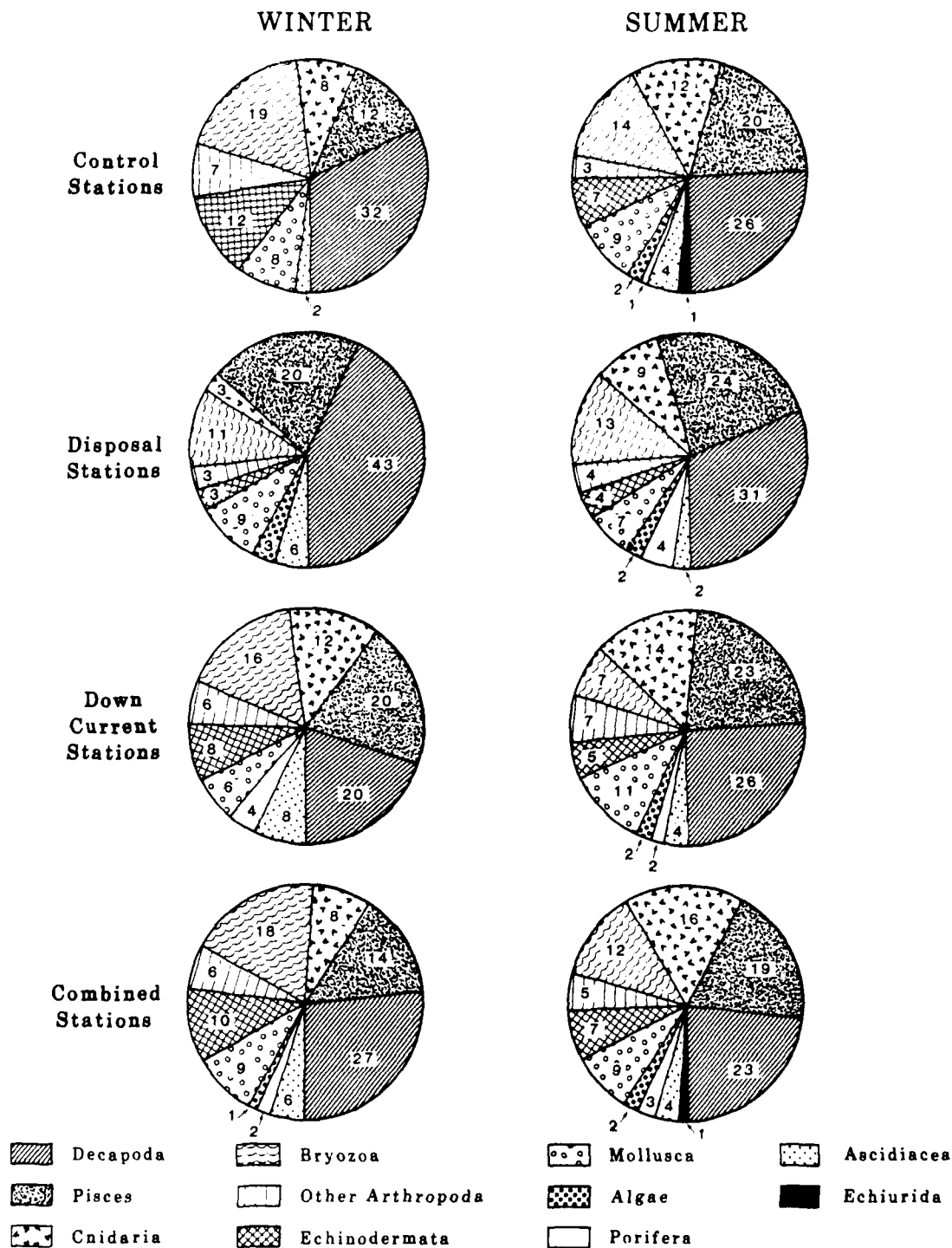


Figure 14. Percentage contribution of major taxa to the species composition of beam trawl collections.



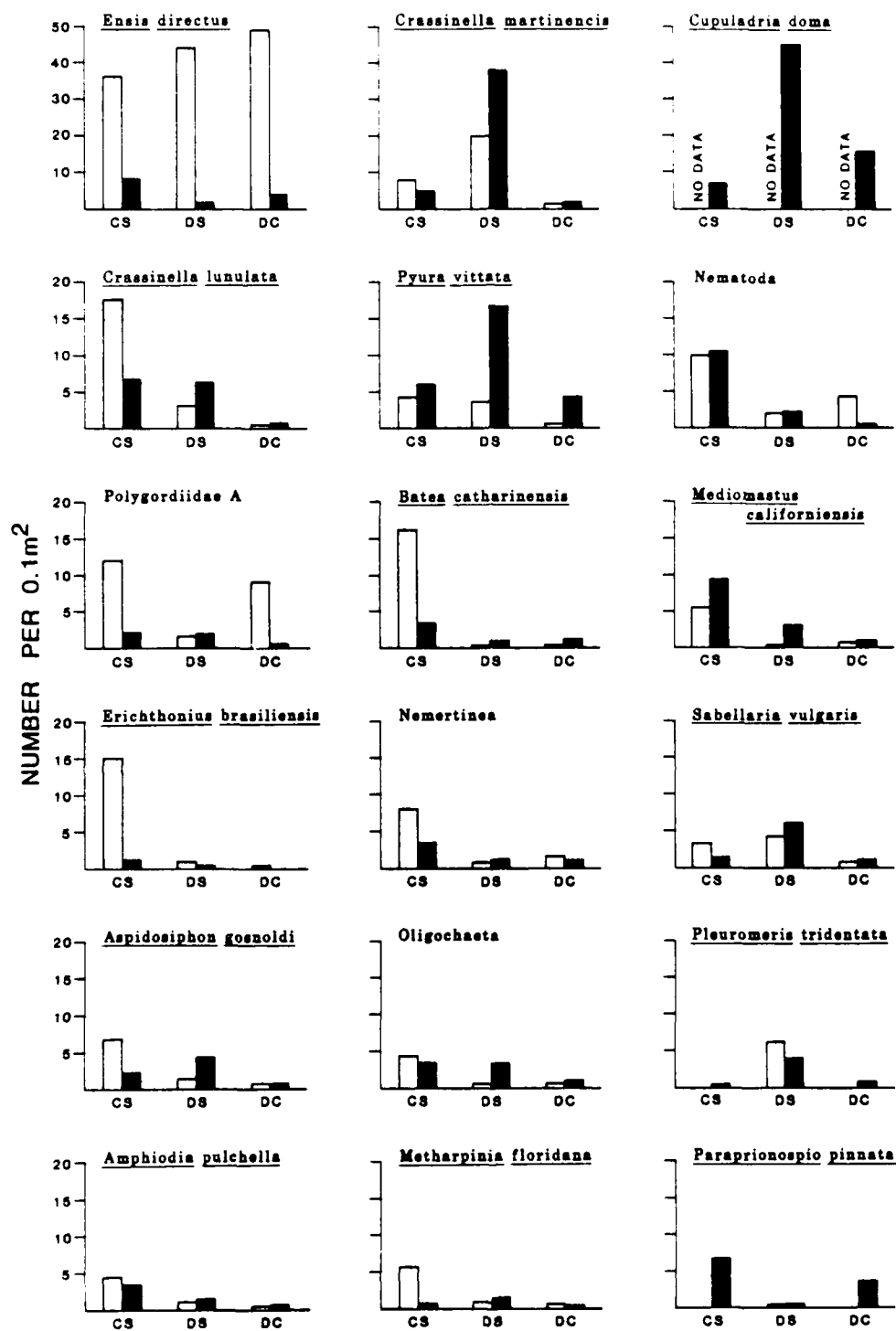


Figure 19. Comparison of the mean density of dominant macroinvertebrates from grab samples at control (CS), disposal (DS), and "down current" (DC) sites. Only species represented by more than 1% of the total number of individuals are included. (Open bars are winter, solid bars are summer).

Table 15. Mean density of the dominant macroinvertebrates at control, disposal, and "down current" sites during each season. Values are the number of individuals per 0.1 m<sup>2</sup>.

	CONTROL STATIONS		DISPOSAL STATIONS		DOWN CURRENT STATIONS	
	WINTER Mean Density	SUMMER Mean Density	WINTER Mean Density	SUMMER Mean Density	WINTER Mean Density	SUMMER Mean Density
<u>Ensis directus</u>	36.4	8.6	44.1	2.1	49.2	4.1
<u>Crassinella martinicensis</u>	8.4	4.7	19.7	38.0	0.6	1.7
<u>Cupuladria doma</u>	no data	6.8	no data	44.8	no data	16.5
<u>Crassinella lunulata</u>	17.9	6.8	2.9	5.9	0.1	0.2
<u>Pyura vittata</u>	3.9	6.3	3.4	16.6	0.4	3.9
<u>Nematoda</u>	9.6	10.3	1.7	1.8	4.1	0.3
<u>Polygordiidae A</u>	12.3	2.1	1.5	1.6	8.9	0.5
<u>Batea catharinensis</u>	15.9	2.9	t	0.8	0.1	1.1
<u>Mediomastus californiensis</u>	5.4	8.8	0.1	2.9	0.4	1.0
<u>Fritchthonius brasiliensis</u>	15.0	1.6	0.4	0.2	0.2	0
<u>Nemertinea</u>	7.9	2.9	1.4	1.6	1.7	1.4
<u>Sabellaria vulgaris</u>	2.9	1.4	3.6	6.0	1.0	1.5
<u>Aspidosiphon gosnoldi</u>	6.8	2.2	1.4	4.0	0.3	0.3
<u>Oligochaeta</u>	4.0	3.8	0.4	3.3	0.4	1.7
<u>Pleuromeris tridentata</u>	0	0.2	6.4	3.7	0	0.5
<u>Amphiodia pulchella</u>	4.1	3.5	0.7	1.0	0.3	0.5
<u>Metharpinia floridana</u>	5.5	0.7	1.2	1.5	0.2	0.1
<u>Paraprionospio pinnata</u>	0	6.8	t	0.2	0	3.5

This bivalve typically spends most of its time on the top of the substrate rather than buried in it, climbing on bits of shell by means of its foot and delicate byssal threads (Harry, 1966). It has previously been reported as an important member of the benthic macrofauna in the entrance channel of Winyah Bay (Hinde et al., 1981), where it was largely restricted to sandy sediment. In the present study, it was significantly more dense in the control site than at the disposal and "down current" stations during winter sampling ( $P < 0.02$ ), although no such pattern was observed among collections taken during the summer (Figure 18).

The fifth most abundant species was the solitary ascidian, *Pyura vittata*. This small ascidian is found in shallow water attached to small bits of shell or stone (Van Name, 1945; Plough, 1978). Its pattern of density among our stations resembled that of *C. martinicensis* and *C. doma*, in that it was most common in the summer in the disposal site (Figure 19). Like those species, however, this pattern was not statistically significant ( $P > 0.05$ ). Comparisons of mean densities among sites and seasons for the remaining dominant species resulted in only one other significant difference. During both seasons, the polychaete *Mediomastus californiensis* was more abundant at control stations than elsewhere (Figure 19), and in winter the difference between CS stations and DS stations was significant ( $P < 0.05$ ).

The two most abundant macroinvertebrates collected in the Charleston DMDS were the lancelet *Branchiostoma caribaeum* and the sipunculid *Aspidosiphon gosnoldi* (reported as *A. spinalis*; Van Dolah et al., 1983). Although *A. gosnoldi* was also found in higher densities in the Georgetown DMDS (Figure 19), *B. caribaeum* was not nearly as common (Appendices 5-10). This difference between the two disposal sites is noteworthy, although not easily explained. It could be due, in part, to the relative mobility of the lancelet, which is often taken in surface water samples (Boschung and Gunter, 1962), and to differences in the availability of suitable shell substrate, which is necessary for large populations of the nestling sipunculid (Cutler, 1973).

The spionid polychaete *P. pinnata*, which was abundant during the summer in the control and "down current" sites, was also among the dominant species collected during October in the entrance channel to Winyah Bay (Hinde et al., 1981). In that study, it was found in finer sediments of the channel (> 93% silt and clay), and in another study of dredge spoil disposal effects it appears to have been transported to the disposal site via dredged material (Van Dolah et al., 1979).

The diversity of the benthic communities was compared among sites and seasons using several indices of community structure (Appendix 11). To facilitate this comparison, the average value of each of the following parameters was plotted for each site and

season: diversity ( $H'$ ), evenness ( $J'$ ), species richness (SR), number of species, and abundance (Figure 29).

Average diversity was greatest in the control site and it was most variable in the disposal site where values of 1.4 and 5.8 were obtained at DS11 (winter) and DS08 (summer), respectively. Within each particular area, diversity was generally greater during the summer. Diversity noted at the control site during both seasons was similar to the rather high values reported in the Charleston DMDS (Van Dolah, et al., 1983), while diversity noted in the disposal and "down current" sites was more typical of similar nearshore environments in the Middle Atlantic Bight (Boesch, 1972; Boesch et al., 1977) and further north (Saila et al., 1972).

No obvious differences in evenness ( $J'$ ) were observed among sites; however, a consistent seasonal pattern was detected with average values of  $J'$  being greatest during the summer at all areas (Figure 20). Like  $H'$ , this index was also highly variable among disposal stations, and extreme values were observed at DS08 and DS11, the same stations which exhibited extreme  $H'$  values. In the winter, DS11 was heavily dominated (> 81%) by *E. directus* (Appendix 7), which reduced species equitability ( $J' = 0.3$ ), whereas the four dominant species in summer collections at DS08 comprised only 24% of the total number of individuals at that station (Appendix 8).

Species richness (SR) was greatest at control sites, where it exhibited rather marked variation among samples (Figure 20). The highest value was observed at CS10 during winter (23.9), while the lowest value occurred at DC03 during that season (4.6). Control stations also differed from disposal and "down current" sites in that winter samples had higher SR than those taken during summer.

Comparisons of overall faunal abundance at stations within each site indicated that densities were generally highest at the control site during the winter, with a maximum of 3,120 individuals per 0.5 m<sup>2</sup> at CS10 (Figure 20). The lowest average density was observed at "down current" stations, with only 78 individuals per 0.5 m<sup>2</sup> collected at DC03. Overall faunal abundance was highly variable among the stations (Appendix 11); however, no statistically significant seasonal or spatial patterns of total abundance were detected ( $P > 0.2$ ).

The average number of species per station was highest in the control site during winter (Figure 20), where as many as 193 species were obtained in 5 replicate 0.1 m<sup>2</sup> samples at CS10 (Appendices 5 and 11). The fewest species were collected at the "down current" site, where winter collections at DC03 yielded only 21 species in the five grab samples (Appendices 9 and 11). Coincidentally, these were the same stations having the highest and

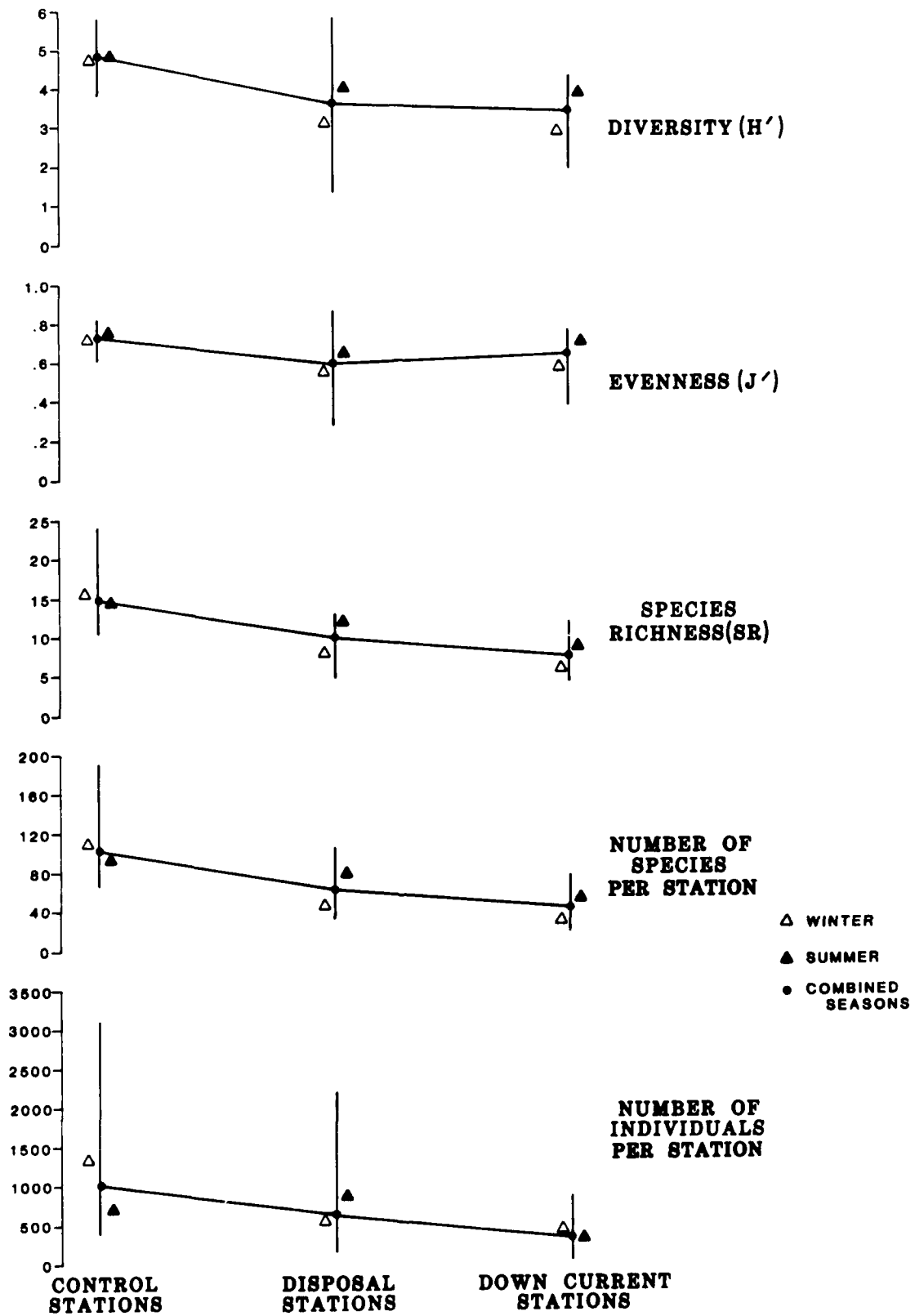


Figure 20. Average values of several community structure parameters at control, disposal, and "down current" sites. The vertical bars indicate the range of values for each site.

lowest overall faunal densities, respectively. The difference in mean number of species between CS and DS stations was significant during the winter period ( $P < 0.02$ ), but by summer the difference between areas was no longer significant ( $P > 0.05$ ).

The relatively high number of species, faunal density, and diversity of the benthic community observed during winter at the control stations (Figure 20) may be related to differences between sediments in that area and those of the disposal and "down current" areas. Qualitative observations during the winter sampling period indicated the presence of finer sediments in samples from all five control stations. Similar sediments were observed at only one other station in the disposal and "down current" sites during that season. In summer, however, measurements of sediment texture indicated no significant differences in the proportion of fine-grained (silt and clay) sediments among control, disposal and "down current" sites (Table 6). During this period, no obvious differences were noted between control stations and the others based on species richness, diversity and overall abundance (Figure 20). It is unlikely that the distribution of these finer sediments during the winter is related to previous disposal practices. Naturally occurring sediment transport is extensive throughout the study area (Figure 2), and the finer sediments in the control site during winter were probably a result of such processes.

Normal cluster analysis produced five groups of stations with relatively high internal similarity (Figure 21). Some seasonality in community structure was apparent from the arrangement of entities within the dendrogram, since all but one group consisted predominantly of collections from one season or the other. Station groups 2 and 3, for example, were comprised exclusively of summer samples, while groups 4 and 5 were primarily winter collections. Group 1 was an equal mixture of samples from both seasons.

All sampling sites had three stations which were sampled during both seasons (CS02, 09, 13; DS03, 06, 13; DC01, 02, 03). Seven of those stations had winter and summer collections located in different station groups (Figure 21). The remaining two were control stations, CS09 and CS13, indicating smaller seasonal differences in community structure at this site than elsewhere. In fact, group 1, which was equally represented by samples from both seasons, contained nearly all of the CS samples, with the only exceptions being CS02 and CS03 summer samples.

The location of sampling sites belonging to each of the winter station groups further illustrates the difference between the control site and other sites (Figure 22). During this season, the control stations were highly dissimilar to the "down current" and disposal stations, with group 1 being most dissimilar to groups 4 and 5 (Figure 21). This distinction

between sites was no longer apparent in the summer, when station groups were either broadly distributed throughout the study area, or limited to a single station (Figure 23).

The inverse classification produced seven species groups which were dissimilar to one another in terms of their occurrence and abundance among station groups (Figure 24, Table 16). Nodal diagrams were constructed to illustrate the distribution of species groups among "fixed" site groups (CS, winter and summer; DS, winter and summer; DC, winter and summer) in order to elucidate possible differences between these sites and/or seasons.

Species group A contained a large number of ubiquitous species that included most of the numerically dominant organisms (Tables 15, 16). These species were highly constant at all sites, especially in the control area, and consequently showed only low fidelity to site groups (Figure 24). Several species in this group, including *C. lunulata*, *Amphiodia pulchella*, and *Metharpinia floridana* were restricted to sandy sediments in the Georgetown entrance channel (Hinde et al., 1981), although no such sediment preferences are apparent from their distribution in the present study.

Group B consisted mainly of polychaetes, ophiuroids and mollusks that were highly constant among control stations during the winter. Their constancy at other sites was moderate to very low, and as a result this group was moderately faithful to the control area. This was the only species group that was even moderately site-restricted (Figure 24). Species in group C showed moderate to low constancy and low fidelity among all site groups.

Species in groups D and E showed greater similarity to one another than to any other groups, and the distribution of their component species among site groups was very similar (Figure 24). These species showed seasonal variation in abundance at all sites, with constancy in summer samples being consistently greater than in winter. They were also more constant at control and disposal sites than at "down current" sites, although they were not highly restricted to any area (Figure 24).

Group F contained several of the more abundant species, including *P. tridentata*, *C. martincensis*, *P. vittata* and *A. gosnoldi* (Table 15, 16). All of these species, except *A. gosnoldi*, were greatest in abundance at the disposal site (Figure 19), and this is reflected in the high constancy of this group at that site (Figure 24). High constancy was also observed for this group at the "down current" stations during summer. Fidelity for this group was low at all sites.

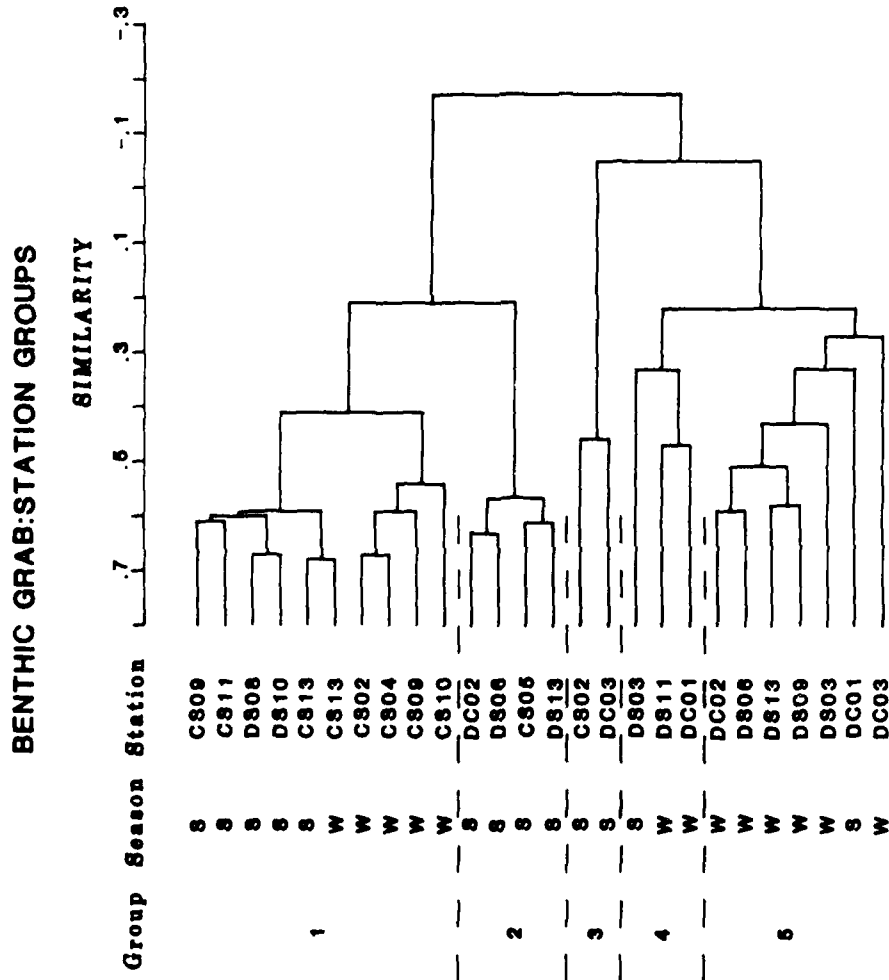


Figure 21. Normal cluster dendrogram of benthic grab samples showing the five station groups formed using flexible sorting.

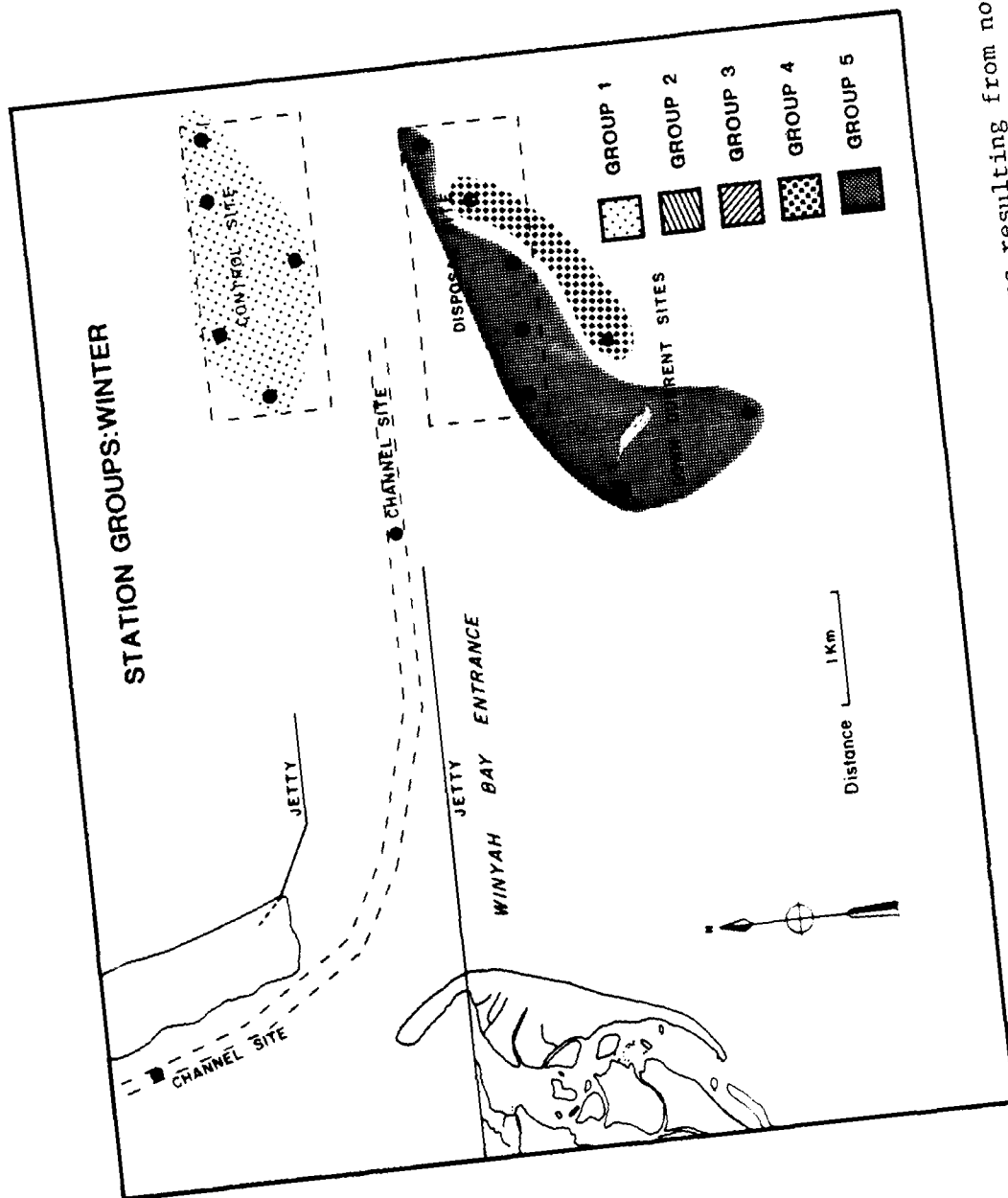


Figure 22. Location of the winter samples among station groups resulting from normal cluster analysis. See Figure 21 for levels of similarity.

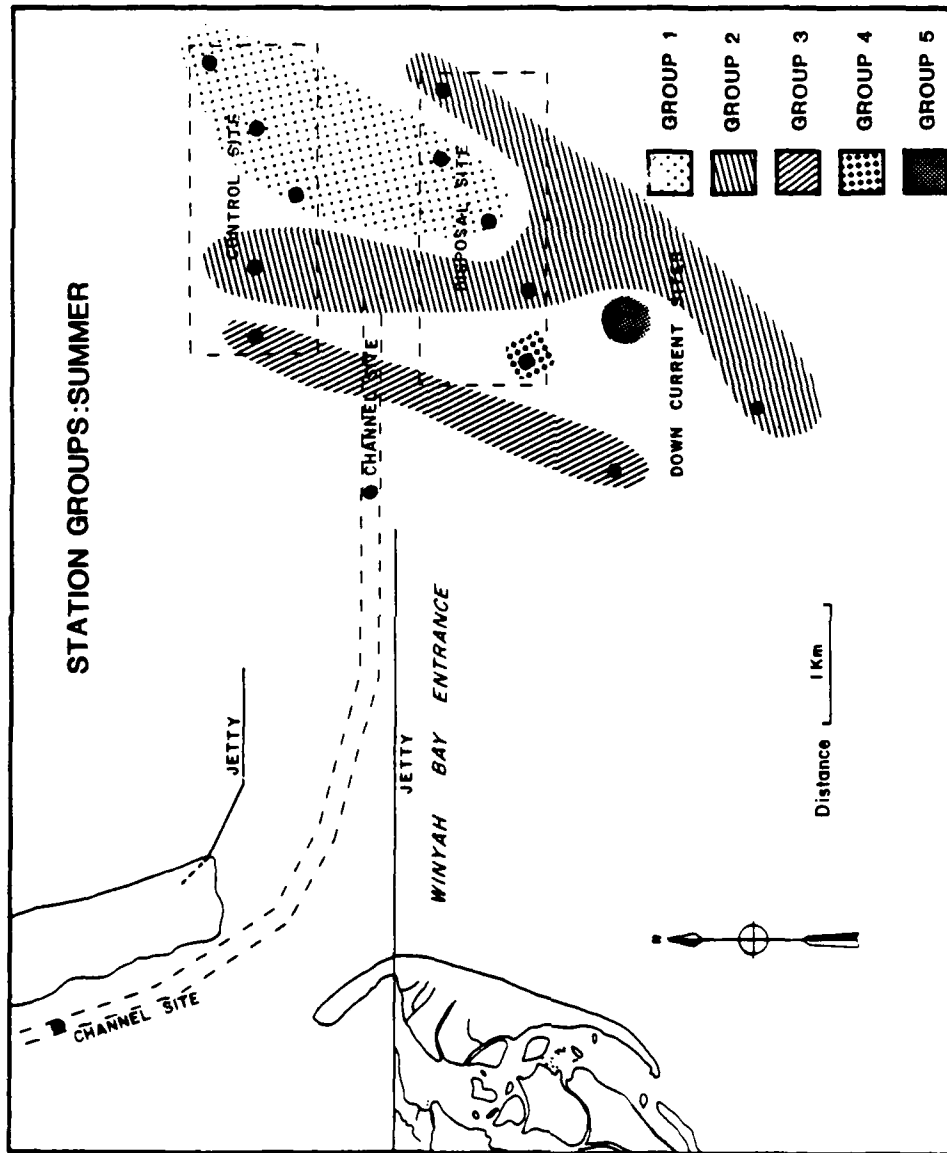


Figure 23. Location of the summer samples among station groups resulting from normal cluster analysis. See Figure 24 for levels of similarity.



# BENTHIC GRAB:NODAL DIAGRAM

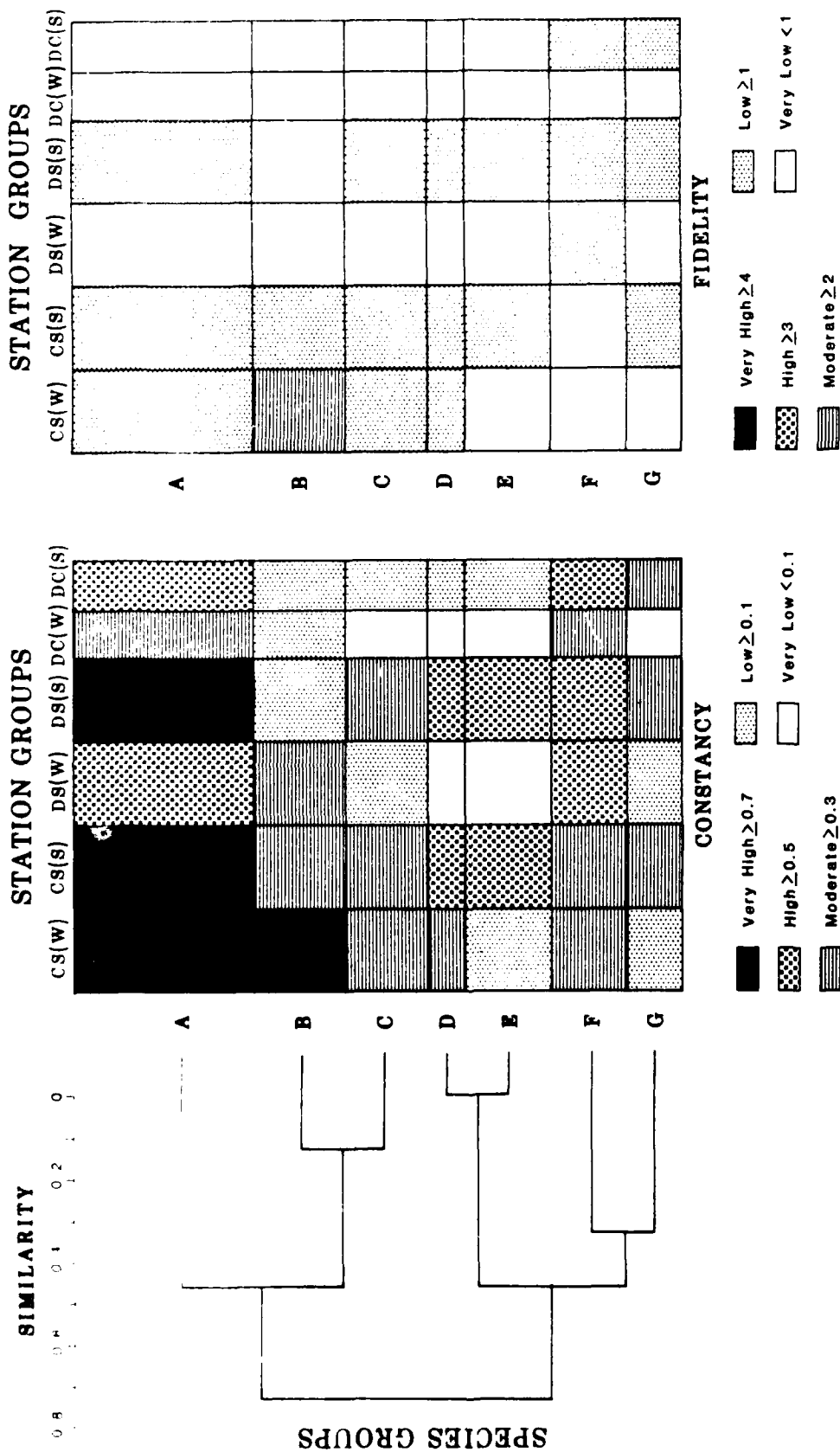


Figure 24. Inverse classification heirarchy of grab collections and nodal diagrams showing constancy and fidelity of species groups among the sampling sites and seasons.

Table 16. Species groups resulting from inverse cluster analysis of grab samples. (Am = Amphipoda; As = Asciadiacea; Ce = Cephalochordata; Cu = Cumacea; D = Decapoda; E = Echinodermata; I = Isopoda; M = Mollusca; My = Mysidacea; P = Polychaeta; Si = Sipunculida).

## Group A

Oligochaeta  
Mediomastus californiensis (P)  
Nemertinea  
Nematoda  
Crassinella lunulata (M)  
Amphiodia pulchella (E)  
Hemipodus roseus (P)  
Sabellaria vulgaris (P)  
Pagurus hendersoni (D)  
Batea catharinensis (Am)  
Ensis directus (M)  
Polygordiidae A (P)  
Actiniaria  
Pelecypoda  
Maldanidae (P)  
Unciola serrata (Am)  
Polycirrus eximius (P)  
Automate evermanni (D)  
Eulalia sanguinea (P)  
Pinnixa sp. (D)  
Spiophanes bombyx (P)  
Nephtys picta (P)  
Glycera sp. A (P)  
Glycera dibranchiata (P)  
Erichthonius brasiliensis (Am)  
Exogone dispar (P)  
Metharpinia floridana (Am)  
Acanthohaustorius millsii (Am)  
Oxyurostylis smithi (Cu)

## Group B

Crepidula fornicata (M)  
Podarke obscura (P)  
Ophiuroidea (E)  
Bhawania goodei (P)  
Hemiphilus elongata (E)  
Nereis sp. (P)  
Nereis succinea (P)  
Notocirrus spiniferus (P)  
Petricola pholadiformis (M)  
Pelecypoda B  
Polydora caeca (P)  
Cirolana polita (I)  
Cirratulidae (P)  
Nucula proxima (M)  
Elasmopus levis (Am)

## Group C

Tharyx annulosus (P)  
Brania clavata (P)  
Ampelisca vadorum (Am)  
Spiophanes sp. A (P)  
Diopatra cuprea (P)  
Turbellaria  
Tharyx marioni (P)  
Invertebrata D  
Parvulicina multilinea (M)  
Pseudeurythoe ambigua (P)  
Prionospio fallax (P)  
Spio pettiboneae (P)  
Ervilia concentrica (M)

## Group D

Ancistrosyllis hartmanae (P)  
Cirrophorus lyriformis (P)  
Goniadides carolinae (P)  
Mysidopsis bigelowi (My)  
Amaena trilobata (P)  
Tiron tropakis (Am)

## Group E

Caulerliella killariensis (P)  
Sigambra bassi (P)  
Ampharete americana (P)  
Schistomeringos rudolphi (P)  
Prionospio cirrifera (P)  
Owenia fusiformis (P)  
Aspidosiphon albus (Si)  
Drilonereis magna (P)  
Paraonidae (P)  
Leptochela serratorbita (D)  
Tiron triocellatus (Am)  
Trachypenaeus constrictus (D)  
Parapionsyllis sp. A (P)  
Promysis atlantica (My)

## Group F

Natica pusilla (M)  
Travisia parva (P)  
Branchiostoma caribaeum (Ce)  
Mellita quinquesperforata (E)  
Ancinus depressus (I)  
Eudevenopus honduranus (Am)  
Glycera oxycephala (P)  
Pleuromeris tridentata (M)  
Ophelia denticulata (P)  
Pyura vittata (As)  
Crassinella martinicensis (M)  
Aspidosiphon gosnoldi (Si)

## Group G

Magelona phyllisae (P)  
Magelona rosea (P)  
Paraprionospio pinnata (P)  
Mulinia lateralis (M)  
Pelecypoda  
Sigambra tentaculata (P)  
Bowmaniella sp. (My)  
Bowmaniella brasiliensis (My)  
Abra aequalis (M)

Finally, group C consisted of a number of species which had moderate constancy and low fidelity to all areas during the summer; lower values were consistently noted during the winter. Nearly half of the species in this group have been shown to prefer finer sediments with a significant silt or clay content. Hinde et al. (1981) found *P. pinnata*, *Mulinia lateralis*, and *Sigambra tentaculata* to be most common in muddy sediments at Winyah Bay, and *Magelona phyllisae* and *P. pinnata* were found in more silty sediments of nearshore waters on the Texas continental shelf (Flint and Rabalais, 1980).

Results of the present study suggest that there have been no long-lasting effects on the benthic infaunal community in the Georgetown DMDS as a result of past disposal activity. This community was characterized by large seasonal and spatial variability in species composition and abundance, which is typical for nearshore environments throughout the South Atlantic Bight (US EPA, 1982). Several noteworthy differences were observed, however, between the infaunal biota of the Georgetown DMDS and the infaunal communities described by the US EPA (1982) off Savannah, Charleston, and Wilmington.

Sediments in the Savannah, Charleston, and Wilmington (SCW) DMDS were characterized primarily as fine to medium sand (US EPA, 1982), while those in the Georgetown site were typically medium to coarse. In addition, greater numbers of species were collected from stations sampled during the present study than from the SCW-DMDS. Other studies off the South Carolina coast, however, indicate that the number of species observed at these Georgetown stations may actually be more typical of similar nearshore environments in the vicinity (Knott et al., 1983b; Van Dolah et al., 1983). Finally, the dominance of the SCW-DMDS by small-bodied deposit-feeders (US EPA, 1982) was not observed in the Georgetown disposal site, where the five most abundant species were the suspension feeders *E. directus*, *C. martinicensis*, *C. doma*, *C. lunulata* and *P. vittata*.

Although some of the effects of dredged material disposal, such as increased turbidity, may be transient or localized (Windom, 1976), the impacts of such a disruption would certainly be more severe on a suspension-feeding community such as that found in the Georgetown DMDS, than on a community dominated by deposit feeders. The effects of disposal would be even more obvious if the textural characteristics of disposed sediments were significantly different from the medium-coarse sandy sediments observed throughout this study area. The importance of matching the physical characteristics of the dredged material as closely as possible to the substrate found in the disposal site, in order to minimize potential disruption to the benthic community, has been previously acknowledged (Windom, 1976; Morton, 1977; US EPA, 1982).

#### Tissue Chemistry

Factors influencing contaminant concentrations in marine organisms include the size and health of the organism, its feeding habits, and its physical location (i.e. within or above the bottom sediments, in the water column, etc.). Depending upon the organism's ability to concentrate a particular contaminant, tissue levels may differ greatly from those in the surrounding environment. For example, oysters examined in the Wando River near Charleston were found to have copper concentrations  $> 200 \mu\text{g/g}$ , whereas copper levels in the water were below the detection limit (Mathews et al., 1979). Some typical examples of trace metal concentrations in edible tissue are as follows: 4.0-5.0 ppm arsenic in crustaceans, 0.1-0.3 ppm cadmium in molluscs and crustaceans, 0.3-0.4 ppm chromium in hard clams (*Mercenaria mercenaria*) and oysters (*Crassostrea virginica*), 2.0-3.0 ppm copper in hard clams and 30.0-40.0 ppm copper in oysters, 0.5-0.8 ppm lead in molluscs and crustaceans,  $< 0.3$  ppm mercury in crustaceans and  $< 0.1$  ppm mercury in molluscs, 0.2-0.4 ppm nickel for crustaceans, and 10.0-20.0 ppm zinc in hard clams (Hall et al., 1978).

Trace metal concentrations in tissue samples from the three sites sampled during this study were consistently within the limits described above, indicating no unusual accumulation of metals in organisms from this small geographical area. Appendix 12 presents data for all metals analyzed, while Table 3 shows the maxima. Cadmium, chromium, nickel, lead and mercury were all below their particular detection limits and well within the scope of values reported in the survey by Hall et al. (1978). Both arsenic and copper fell within the above limits, with values of 1.67-2.34  $\mu\text{g/g}$  and 6.15-9.65  $\mu\text{g/g}$ , respectively. Although zinc was somewhat higher than the concentrations listed above (50.77-53.61  $\mu\text{g/g}$ ), oysters commonly contain zinc ranging from 300-400 ppm (Hall et al., 1978).

No pesticides or PCBs were detected in any of the tissue samples using detection limits of  $\geq 50$  ppb. Consequently, we assume these contaminants are present in trace quantities only.

#### RECOMMENDATIONS AND SUGGESTED MONITORING PLAN

The Georgetown DMDS is an easily accessible area for monitoring the effects of dredged material disposal. Based on results obtained from this study we have several recommendations related to environmental and biological assessment in future monitoring efforts.

1) Hydrographic sampling conducted during the present study provided a satisfactory data base for a general evaluation of oceanographic conditions. This sampling effort would not have to be expanded in future assessments.

2) Sampling for trace metals and organic pollutants was also sufficient in terms of the array of pollutants examined. However, the current detection limits for pesticides and PCBs suggested by Pequegnat et al. (1981) may be too high for a proper evaluation of potentially toxic conditions. McKee and Wolf (1963) and Bookhout and Costlow (1976) indicate that trace amounts much lower than the suggested limit of these compounds ( $\leq 50$  ppb) may be lethal to certain organisms. Therefore, we recommend lowering detection limits to at least 1-3 ppb for the PCBs and pesticides tested. Priority should be given to testing pollutant levels in sediments and animal tissue rather than in water since the hydrographic conditions in the study area are so variable.

3) Sedimentological analyses in this study were limited to only one season, but qualitative observations during the other season suggested temporal differences in sediment composition. Therefore, sediment composition and grain-size analyses should be conducted concurrent with every future biological sampling period for a better understanding of faunal distribution patterns. Assessment of contaminants in sediments could be limited to the sampling period(s) immediately following disposal operations. If high levels of pollutants were then detected, an expanded follow-up sampling program should be conducted for those pollutants.

4) Review of topographic data available for the Georgetown DMDS area did not reveal any obvious mounding from previous disposal activities. To better evaluate potential effects of disposal on benthic communities in the DMDS, the Corps of Engineers should require dredge operators to provide precise Loran-C coordinates for all disposal activities. Loran-C receivers are inexpensive and sufficiently accurate to locate potential mound sites. Additionally, we recommend that detailed bathymetric profiles be obtained for the DMDS area immediately after a disposal period, and then again at reasonable intervals for at least one year following disposal. This would permit placement of future monitoring stations in known disposal areas and help in evaluating dispersal of sediments over time.

5) Based on the poor visibility and dangerous current conditions in the study area, we recommend deletion of scuba diving in any future monitoring efforts.

6) The benthic community assessment in the DMDS, control and "down current" areas provided sufficient data on present community composition, as well as information on the temporal and spatial distribution of dominant fauna. Because negative effects of past disposal activities were not noted in this study, future monitoring activities in the Georgetown DMDS area should not need to be intensive, unless (1) a significantly larger amount of sediment is disposed in the area or (2) sediments are disposed in the DMDS which are significantly different from those naturally present. Disposal of larger sediment volumes and/or disposal of finer sediments from Winyah Bay, especially from around Georgetown Harbor, could possibly have more severe and long-term effects on the benthic infauna in and near the DMDS. These effects would most likely be due to direct burial, changes in sediment composition and increased turbidity (Morton, 1977). Thus, intensive biological monitoring would be needed for impact assessment.

7) Any future monitoring program should consider seasonal effects on benthic community composition. If possible, priority should be given to summer and winter periods for best comparisons with data obtained from this study. Infaunal assemblages represent the most important biological component for assessment of impacts from disposal. Epifaunal assemblages are also important, particularly for collection of large animals for tissue analysis, but assessment of impacts on this group is more difficult, since most epifaunal species are relatively motile.

As noted previously, information obtained in this study indicates that past disposal practices in the Georgetown DMDS have not resulted in detectable negative impacts to resources and biota in and near the existing disposal site. Therefore, use of this area for disposal of outer-channel sediments (similar volumes) can be continued, although consideration should be given to avoiding seasons critical to the sturgeon and shrimp fisheries. Alternatively, the site could be relocated further offshore to avoid seasonal restrictions related to these fisheries. The present location of the DMDS may not be suitable if finer sediments were disposed in the area, due to the strong tidal currents present and the location of the DMDS relative to shrimp and sturgeon fisheries and turtle nesting grounds. Our present information base is insufficient to predict the effects of offshore disposal of fine sediments on these resources or on benthic communities.

## Summary and Conclusions

1. The Georgetown Ocean Dredged Material Disposal Site was assessed to provide baseline information on present conditions related to the hydrography, bottom sediments and benthic communities. Narrow areas to the north and south, as well as in the entrance channel to Georgetown Harbor, were also assessed for comparison with conditions found in the DMDS.

2. A survey of existing information related to living and non-living resources in the region around Winyah Bay generally supported conclusions and conditions described by the US EPA (1982) for the Savannah, Charleston and Wilmington DMDS. Specific resources which might be affected by disposal in the Georgetown DMDS include the shrimp and Atlantic sturgeon fisheries, and loggerhead turtles (nesting). The sturgeon fishery is the most localized of these three resources, and Winyah Bay is the site of the biggest fishery for this species in the Sea Island region. Other living and non-living resources in the study area will probably not be affected by disposal of predominantly sandy sediments from the outer reaches of the Winyah Bay entrance channel. Disposal of finer sediments from Georgetown Harbor or other areas, however, would possibly have more detrimental effects on the surrounding resources due to increased turbidities and changes in sediment composition. Sufficient studies have not been conducted in this region to fully evaluate the consequences of fine-sediment disposal in offshore sand bottom areas.

3. Sampling was conducted at five sites in the DMDS, five sites in a control area north of the DMDS, three "down current" sites south of the DMDS, and two channel sites. The number of samples varied at each site, but hydrographic, sediment and benthic grab and trawl samples were collected at most stations during summer and winter seasons.

4. Standard hydrographic factors, which included temperature, salinity, dissolved oxygen and turbidity were within the limits normally encountered along the South Carolina coast. Some seasonal and spatial differences were discerned for each factor. High runoff via Winyah Bay resulted in reduced salinities and increased turbidities at some sites. Moderately high turbidities in summer may have been the result of frequent shrimp trawling in the area. Currents in the DMDS appear to be largely tidal, although some evidence of a southerly nearshore current was noted. Trace contaminants in water samples were within or below ranges noted in other areas of the South Atlantic Bight. Many trace metals were below detection limits, as were PCBs and all pesticides tested.

5. Sediment analyses indicated that bottom sediments at most of the sampling sites consisted of medium to coarse sands with very little (< 1%) silt and clay. Stations to the south of the DMDS had consistently finer-grained sediments than those in the DMDS and control areas, but no statistically significant differences were noted among sites. Sediments were low in trace metal and organic contaminant concentrations. Comparisons with other studies indicated that sediments in and near the Georgetown DMDS cannot be considered polluted. No hard bottom areas were found in the entire study area.

6. Benthic epifauna and fishes captured in beam trawl collections were typical of those from sand bottom habitat of South Carolina coastal waters. Community structure was influenced by season, and the number of species was significantly higher in summer. Species assemblages differed noticeably between winter and summer, with several species occurring during only one season. Although the total number of species was lowest in the disposal area, comparison of species composition among the sites indicated that lower diversity resulted from fewer sessile species, mainly bryozoans and cnidarians. This suggests that less hard substrate was available for colonization by sessile organisms in portions of the disposal area, although lesser amounts of hard substrate (i.e. wood, shell) in the DMDS were probably not related to past disposal activities. Tissue analysis of whelks (*Busycon carica*) collected in and near the DMDS did not reveal any high concentrations of contaminants.

7. The infauna collected in grab samples at the 13 offshore stations were numerically dominated by pelecypods, polychaetes, amphipods and bryozoans. Polychaetes were the most diverse taxon. Of the 357 species collected, many were rare or limited in their distribution. The dominant species, however, were generally ubiquitous throughout the study area and exhibited considerable temporal and spatial variation. No significant differences could be attributed to past disposal activities with respect to species composition or faunal density among the control, disposal and "down current" sites. Unlike the deposit-feeding communities previously described for the SCW-DMDS, the Georgetown DMDS and vicinity were characterized by a seasonally variable, diverse community of suspension-feeding organisms. Numerical classification of the data illustrated some differences in similarity between stations in the control site versus those in the disposal and "down current" areas, particularly during winter. These differences probably were not related to previous disposal practices. Rather, they were most likely due to natural variability in sediment composition. Cluster analysis also indicated that most of the abundant and frequently occurring species were widely distributed throughout the study area.

8. Recommendations for future monitoring at the Georgetown DMDS include lowering the detection limits required for organic contaminants, deleting diver observations, increasing sedimentological and bathymetric surveys, and increasing the intensity and scope of assessments if increased volumes of fine-grained sediments are deposited in the DMDS. The present location of the Georgetown DMDS appears to be satisfactory for continued disposal of outer-channel sediments.

9. An alternative disposal site located farther offshore would reduce potential localized impacts on the shrimp and sturgeon fisheries. Although no evidence was found which indicated that past (limited) disposal in the DMDS has had a significant impact on these fisheries, disposal of finer-grained sediments in the present DMDS might have greater effects.

## Literature Cited

- Allen, D.M., S.E. Stancyk, and W.K. Michener, eds. 1982. Ecology of Winyah Bay, S.C. and potential impacts of energy development. Univ. of S.C., Baruch Institute, Special Publication No. 82-1, 275 p.
- Boesch, D.F. 1972. Species diversity of marine macrobenthos in the Virginia area. Chesapeake Science 13: 206-211.
- Boesch, D.F. 1977. Application of numerical classification in ecological investigations of water pollution. Corvallis, OR: U.S. Environmental Protection Agency, Office of Research and Development. Rept. No. EPA-600/3-77-033. 114 p.
- Bookhout, C.G. and J.D. Costlow. 1976. Effects of mirex, methoxychlor, and malathion on development of crabs. Prepared by Duke University Marine Laboratory for U.S. Environmental Protection Agency. Report No. EPA-600/3-76-007.
- Boschung, H.V. and G. Gunter, 1962. Distribution and variation of Branchiostoma caribaeum in Mississippi Sound. Tulane Studies in Zoology 9: 245-257.
- Bothner, M.H., P.J. Aruscavage, W.M. Ferrebee, and P.A. Baediecker. 1980. Trace metal concentrations in sediment cores from the Continental Shelf off the Southeastern United States. Estuarine and Coastal Marine Science 10: 523-541.
- Bureau of Land Management. 1981. Final environmental impact statement, proposed 1981 Outer Continental Shelf Oil and Gas Lease Sale 56. U.S. Department of the Interior. New Orleans, LA.
- Chen, F.Y., S.F. Gupta, A.A. Szeip, and J.C.S. Lu et al. 1976. Research study on the effect of dispersion, settling and resedimentation on migration of chemical constituents during open water disposal of dredged materials. U.S. Army Waterways Experimental Station, Tech. Rept. WS 76-1, 221 p.
- Chester, R. and J.H. Stoner. 1974. The distribution of zinc, nickel, manganese, cadmium, copper, and iron in some surface waters from the world ocean. Marine Chemistry 2: 17-32.
- Churgin, J. and S.J. Haiminski. 1974. Temperature, salinity, oxygen, and phosphate in waters off United States. Volume I. Western North Atlantic. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service.
- Clifford, H.T. and W. Stephenson. 1975. An introduction to numerical classification. New York, NY: Academic Press.
- Cory, R.L. and E.L. Pierce. 1967. Distribution and ecology of lancelets (Order Amphioxii) over the continental shelf of the southeastern United States. Limnology and Oceanography 12: 650-656.
- Cutler, E.B. 1973. Sipunculida of the western North Atlantic. Bulletin of the American Museum of Natural History 152:103-204.
- Davis, J.S., M.D. McKenzie, J.V. Miglarese, et al., eds. 1980. Ecological characterization of the Sea Island coastal region of South Carolina and Georgia. Resource Atlas. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-79/40. 56 p.
- Day, J.H., J.G. Field, and M.P. Montgomery. 1971. The use of numerical methods to determine the distribution of the benthic fauna across the continental shelf of North Carolina. Journal of Animal Ecology 40: 93-125.
- Federal Register Vol. 44, No. 223, p. 69568. 1979.
- Federal Register Vol. 44, No. 244, p. 75028. 1979.
- Flint, R.W. and N.N. Rabalais. 1980. Polychaete ecology and niche patterns: Texas continental shelf. Marine Ecology - Progress Series 3:193-202.
- Folk, R.L. 1965. Petrology of sedimentary rocks. Hemphill Publ. Co., Austin, Tex. 64 p.
- Frankenberg, D. and A.S. Leiper. 1977. Seasonal cycles in benthic communities of the Georgia continental shelf. in B.C. Coull, ed., Ecology of Marine Benthos. Univ. of S.C. Press. pp. 383-397.
- Hall, R.A., E.G. Zook, and G.M. Meaburn. 1978. National Marine Fisheries Service survey of trace elements in the fishery resource. National Oceanic and Atmospheric Administration Tech. Rep. NMFS SSRF-721. 313 p.
- Hammond, D.L. and D.M. Cupka. 1978. An economic and biological evaluation of the South Carolina pier fishery. South Carolina Marine Resources Center Technical Report Number 20. 14 p.



	CS02	CS04	CS05	CS09	CS10	CS11	CS13	DS03	DS06	DS08	DS09	DS10	DS11	DS13	DC01	DC02	DC03
<u>Callinectes</u> sp.					W		W	W							S	S	W
<u>Cancer irroratus</u>									S								
<u>Chelonia patula</u>																S	
<u>Conopea galeata</u>																	
<u>Hepatus epheliticus</u>	S		S	S		S			W,S	S					S	S	
<u>Hexapanopeus angustifrons</u>	S					S										S	
<u>Hypoconcha sabulosa</u>							W										
<u>Libinia dubia</u>																	
<u>Libinia emarginata</u>	W,S				W	S	W	W		S			W		W		W
<u>Libinia</u> sp.													W				
<u>Limulus polyphemus</u>				W													
<u>Menippe mercenaria</u>	S			S													
<u>Metoporphaphis calcarata</u>					W												
<u>Nanoplax xanthiformis</u>	S			S													
<u>Neopanope sayi</u>					W			W									W
<u>Ovalipes ocellatus</u>			S	W,S		S			W,S	S	W			W,S	W	W,S	
<u>Ovalipes stephensoni</u>	W,S	W	S	W,S	W	S	S	W,S	W,S	S	W	S	W	W,S	W,S	W,S	
<u>Pagurus hendersoni</u>		W															
<u>Pagurus longicarpus</u>	W,S		S		W		W,S		S	S				W	S	W,S	S
<u>Pagurus pollicaris</u>	S	W	S	S	W	S			S	S		S			S	S	S
<u>Penaeus aztecus aztecus</u>	S		S	S				S		S					S	S	S
<u>Penaeus setiferus</u>				S													
<u>Penaeus</u> sp.									S			S					
<u>Persephona mediterranea</u>						S											
<u>Pilumnus dasypodus</u>								W									W
<u>Pilumnus sayi</u>					W	S											
<u>Porcellana sayana</u>						S		W									
<u>Portunus gibbesii</u>						S											
<u>Portunus spinimanus</u>	W,S		S	W	W	S	W,S	W,S	S	S	W	S	W	W	W,S	W,S	W
<u>Sicyonia brevirostris</u>			S		W	S	S			S	W	S			S		W
<u>Squilla empusa</u>	S			S	W	S									S		W
<u>Squilla neglecta</u>															S		
<u>Trachypenaeus constrictus</u>															S		W
<u>Upogebia affinis</u>	W,S		S	W			W	W,S	S	S	W		W		S	W,S	W
<u>Xanthidae</u> A		W					W										
Echinodermata																	
<u>Arbacia punctulata</u>		W	S		W	S	S										
<u>Asterias forbesii</u>		W	S		W	S	W								S		W
<u>Asterioidea</u> A						S	S										
<u>Astropecten duplicatus</u>			S	S	W	S	S										
<u>Luidia clathrata</u>					W	S											
<u>Lytechinus variegatus</u>					W	S	S										W
<u>Mellita quinquesperforata</u>					W	S	S										
<u>Ophiothrix angulata</u>	S		S		W	S	S		W,S	S		S			S	S	W,S
<u>Ophiuroidea</u> A																	
<u>Ophiuroidea</u> B					W												
<u>Sclerodactyla briareus</u>					W												W,S



## Appendix 4. (Cont Inued)

	CS02	CS04	CS05	CS09	CS10	CS11	CS13	DS03	DS06	DS08	DS09	DS10	DS11	DS13	DC01	DC02	DC03
<i>Celleporaria albirostris</i>													W				
<i>Crisia</i> sp.	S											S				W	
<i>Electra monostachys</i>		W	S			S											
<i>Hippaliosina rostrigera</i>			S			S											
<i>Hippoporina contracta</i>			S		W	S											
<i>Hippoporina verrilli</i>		W				S								S		W	
<i>Membranipora arborescens</i>	S		S	S	W	S			S			S	W		S	W,S	S
<i>Membranipora tenuis</i>	S	W	S	W	W	S				S		S	W		S	W	W
<i>Microoporella ciliata</i>						W,S				S		S			S		
<i>Nolella stipata</i>						W,S											W
<i>Parasmittina nitida</i>		W	S	W	W	S	W,S						W				
<i>Reptadeonella hastingsae</i>		W	S			S	W,S					S	W				
<i>Reptadeonella sp.</i>					W	S	W,S										
<i>Schizoporella errata</i>						S						S					W
<i>Schizoporella floridana</i>						S								S			
<i>Stylopoma informata</i>						S										W	
<i>Trypostega venusta</i>			S				W,S										
Phylum Mollusca																	
<i>Anadara ovalis</i>																	W
<i>Barnea truncata</i>																	W
<i>Brachidontes exustus</i>			S														
<i>Busycon canaliculata</i>			S		W						W						
<i>Busycon carica</i>			S														W
<i>Calliostoma pulchrum</i>																	
<i>Chama macerophylla</i>						S								S			
<i>Crepidula fornicata</i>	S		S	S		S	W,S	W				S			S	S	S
<i>Crepidula plana</i>	S		S	S	W	S	S	W				S			S	S	
<i>Ensis directus</i>																	
<i>Eupleura caudata</i>	S					S											S
<i>Lolliguncula brevis</i>	S		S	S					S			S			S		
<i>Polinices duplicatus</i>							S								S		
<i>Sinum perspectivum</i>															S		
<i>Zirfaea crispata</i>					W										S		
Phylum Echiurida																	
<i>Echiurida</i> (undet.)						S											
Phylum Arthropoda																	
<i>Acetes americanus</i>						S											
<i>Alpheus normanni</i>							W									S	S
<i>Arenaeus cribarius</i>									S								
<i>Anoplodactylus lentus</i>	S																
<i>Balanus calidus</i>					W												W
<i>Balanus trigonus</i>																	
<i>Balanus venustus</i>	S		S		W	S	S					S			S	W,S	S
<i>Callinectes sapidus</i>	W,S			S		S			W								
<i>Callinectes similis</i>	S		S						S							S	



## Appendix 3. (Continued)

Values as determined by 0.1N HCL extraction.

	CH01	CH02	CS02	CS05	CS09	CS11	CS13	DS03	DS06	DS08	DS10	DS13	DC01	DC02	DC03
Cadmium $\mu\text{g/g}$	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Chromium $\mu\text{g/g}$	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Nickel $\mu\text{g/g}$	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Copper $\mu\text{g/g}$	< 0.1	0.92	< 0.1	< 0.1	< 0.1	1.69	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Iron $\mu\text{g/g}$	1,154	1,764	1,084	665	1,181	1,330	826	763	698	933	799	1,128	1,009	822	1,156
Lead $\mu\text{g/g}$	< 0.5	4.6	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Zinc $\mu\text{g/g}$	6.05	9.48	7.22	6.65	6.20	10.13	2.77	2.55	2.66	2.78	3.07	2.72	3.64	2.21	5.35

Values as determined by total digestion.

	CH01	CH02	CS02	CS05	CS09	CS11	CS13	DS03	DS06	DS08	DS10	DS13	DC01	DC02	DC03
Cadmium $\mu\text{g/g}$	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Chromium $\mu\text{g/g}$	1.25	14.9	3.72	< 0.1	8.50	5.97	1.22	1.27	1.22	1.26	2.46	1.16	1.22	1.25	9.05
Nickel $\mu\text{g/g}$	< 0.5	9.95	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	5.89	< 0.5	< 0.5	< 0.5	< 0.5
Copper $\mu\text{g/g}$	< 0.1	2.49	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	1.02	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	4.02
Iron $\mu\text{g/g}$	5,075	15,473	4,777	2,175	7,900	8,308	4,216	4,227	2,696	3,333	3,058	2,180	3,648	3,608	11,558
Lead $\mu\text{g/g}$	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Zinc $\mu\text{g/g}$	9.60	41.04	13.39	14.17	20.25	22.89	7.64	11.14	5.38	9.64	10.77	6.03	9.40	7.83	23.77
Arsenic $\mu\text{g/g}$	1.44	1.38	1.44	0.41	1.18	1.44	1.47	0.77	0.36	1.34	1.06	1.36	1.38	1.07	1.36
Mercury $\mu\text{g/g}$	0.27	0.51	0.34	0.35	0.38	0.11	0.35	0.41	0.08	0.61	0.14	0.22	0.42	0.21	0.55

ND - Not Detected; Detection Limit is 50 ppb.

## Appendix 3. (Continued)

	CH01	CH02	CS02	CS05	CS09	CS11	CS13	DS03	DS06	DS08	DS10	DS13	DC01	DC02	DC03	SPIKE CH01
Sum of the n-Alkanes ug/g	ND	ND	2.25	ND	ND	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Sum of the even n-Alkanes ug/g	ND	ND	1.03	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Sum of the odd n-Alkanes ug/g	ND	ND	1.22	ND	ND	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Unresolved Hydro- carbons/Resolved Hydrocarbons ug/g	ND	ND	ND 8.95	ND	ND	ND 1.00	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Pristane + Phytane n-Alkanes ug/g	ND	ND	ND 2.25	ND	ND	ND 0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Odd n-Alkanes/ Even n-Alkanes ug/g	ND	ND	1.22 1.03	ND	ND	0.04 ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Pristane/n-C17 ug/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Phytane/n-C18 ug/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Pristane/ Phytane ug/g	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
n-Alkanes/Branched Hydrocarbons mg/g	ND	ND	2.25 ND	ND	ND	0.04 ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
T.O.C. %	0.086	0.549	0.529	0.047	0.092	0.318	0.124	0.120	0.075	0.082	0.062	0.057	0.810	0.060	0.577	
C.O.D. mg/kg	2880	66300	78200	1800	2600	6900	3300	2930	1.920	2300	1970	1480	88500	1400	34600	
Nitrate as NO <sub>3</sub> mg/g	57.97	278.57	94.59	15.44	25.39	216.66	533.33	17.55	32.66	19.72	19.23	23.85	156	50.77	392	
Nitrate as NO <sub>2</sub> mg/kg	106.28	10.00	8.04	2.28	0.34	2.5	6.34	0.21	2.47	81.31	3.57	2.70	4.46	3.96	27.45	
Soluble Phosphorus as P <sub>04</sub> mg/kg	1.20	1.63	0.914	0.678	0.446	0.231	1.01	1.72	1.44	1.16	0.849	1.37	1.20	0.646	0.304	
Total Phosphorus as P <sub>04</sub> mg/kg	8.43	34.72	15.44	9.00	8.20	14.93	8.11	7.17	11.26	6.76	6.57	5.82	53.13	5.92	27.13	
Oil + Grease mg/kg	<6	687	35	57	206	24	8	<6	<6	32	105	81	507	114	<10	
Total Kjeldahl Nitrogen mg/kg	40	546	266	29	36	105	55	39	20	722	696	807	994	31	399	

Appendix 3. Geochemical analysis of sediments from the Georgetown DMDS area. (CH - channel, CS - control, DS - disposal, DC - down current).

	CH01	CH02	CS02	CS05	CS09	CS11	CS13	DS03	DS06	DS08	DS10	DS13	DC01	DC02	DC03	SPIKE CH01 1254 PCB - 55.7% RECOVERY
PCBs $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
$\alpha$ - BHC $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
lindane $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
heptachlor $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	73% RECOVERY
B-RHC $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
aldrin $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
heptachlor epoxide $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
P,p'-DDE $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
O,p'-DDD $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
O,p'-DDT $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	100.0% RECOVERY
Chlordane $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Dieldrin $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Endrin $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
P,p'-DDD $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
P,p'-DDT $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Wet weight of Sample Extracted $\mu\text{g/g}$	46.3808	47.9552	48.0755	50.3328	49.7783	52.8452	55.0655	52.0564	55.0394	54.7150	58.9654	45.1802	49.3585	55.7648	44.3987	
Dry weight of Sample Extracted $\mu\text{g/g}$	36.5017	32.9932	34.1336	40.1152	40.0218	43.2802	43.9423	41.3848	45.7928	42.5136	47.5261	35.9183	34.3548	45.1695	29.2587	
Z Dry Weight of Wet Weight $\mu\text{g/g}$	78.7	68.8	71.0	79.7	80.4	81.9	79.8	79.5	83.2	77.7	80.6	79.5	69.4	81.0	65.9	
Total Resolved Hydrocarbons by GC $\mu\text{g/g}$	ND	ND	8.95	ND	ND	1.00	ND	ND	ND	ND	ND	ND	ND	ND	ND	
Total Unresolved Hydrocarbons by GC $\mu\text{g/g}$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	

Methoxychlor

100.0% RECOVERY

## Appendix 2. (Continued)

	<u>CH01</u>	<u>CS05</u>	<u>DS08</u>	<u>DC02</u>	<u>CONTROL</u>	<u>SPIKE</u>
Total unresolved Hydrocarbons by GC $\mu\text{g/l}$	ND	ND	ND	ND	ND	
Sum of the n-Alkanes $\mu\text{g/l}$	229.01	159.64	ND	23.37	ND	
Sum of the even n-Alkanes $\mu\text{g/l}$	104.22	115.35	ND	9.62	ND	
Sum of the odd n-Alkanes $\mu\text{g/l}$	124.79	44.29	ND	13.75	ND	
Unresolved Hydrocarbons/Resolved Hydrocarbons $\mu\text{g/l}$	$\frac{\text{ND}}{416.63}$	$\frac{\text{ND}}{259.98}$	ND	$\frac{\text{ND}}{170.18}$	ND	
Pristane + Phytane/n-Alkanes $\mu\text{g/l}$	$\frac{\text{ND}}{229.01}$	$\frac{\text{ND}}{159.64}$	ND	$\frac{\text{ND}}{23.37}$	ND	
Pristane/n-C17 $\mu\text{g/l}$	$\frac{\text{ND}}{14.36}$	$\frac{\text{ND}}{2.40}$	ND	ND	ND	
Pristane/n-C18 $\mu\text{g/l}$	$\frac{\text{ND}}{2.73}$	$\frac{\text{ND}}{1.47}$	ND	$\frac{\text{ND}}{9.62}$	ND	
Pristane/Phytane $\mu\text{g/l}$	ND	ND	ND	ND	ND	
n-Alkanes/Branched Hydrocarbons $\mu\text{g/l}$	$\frac{229.01}{\text{NA}}$	$\frac{159.64}{\text{NA}}$	ND	$\frac{23.37}{\text{NA}}$	ND	
Oil and Grease $\text{mg/l}$	3.0	3.0	4.0	4.0	5.0	
Odd n-Alkanes/ Even n-Alkanes $\mu\text{g/l}$	$\frac{124.79}{104.22}$	$\frac{44.29}{115.35}$	ND	$\frac{9.62}{13.75}$	ND	
Cadmium $\mu\text{g/l}$	0.8	7.1	1.6	3.4	< 0.1	
Arsenic $\mu\text{g/l}$	78.6	92.8	41.4	32.4	< 2.0	
Chromium $\mu\text{g/l}$	1.4	5.3	4.7	2.1	3.0	
Nickel $\mu\text{g/l}$	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	
Copper $\mu\text{g/l}$	< 50	< 50	< 50	< 50	< 50	
Lead $\mu\text{g/l}$	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	
Mercury $\mu\text{g/l}$	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	
Zinc $\mu\text{g/l}$	265	150	172	172	140	

ND = Not Detected; Detection limit is 50 ppb.

Appendix 2. Hydrographic chemical analysis from Georgetown DMDS area.  
(CH - channel, CS - control, DS - disposal, DC - down current)

	<u>CH01</u>	<u>CS05</u>	<u>DS08</u>	<u>DC02</u>	<u>CONTROL</u>	<u>SPIKE</u>
PCBs $\mu\text{g/l}$	ND	ND	ND	ND	ND	1254 PCB - 100.0% Recovery
$\alpha$ -BHC $\mu\text{g/l}$	ND	ND	ND	ND	ND	
lindane $\mu\text{g/l}$	ND	ND	ND	ND	ND	85.2% Recovery
heptachlor $\mu\text{g/l}$	ND	ND	ND	ND	ND	
B-BHC $\mu\text{g/l}$	ND	ND	ND	ND	ND	
aldrin $\mu\text{g/l}$	ND	ND	ND	ND	ND	
heptachlor epoxide $\mu\text{g/l}$	ND	ND	ND	ND	ND	
P,P <sup>1</sup> - DDE $\mu\text{g/l}$	ND	ND	ND	ND	ND	
O,P <sup>1</sup> - DDD $\mu\text{g/l}$	ND	ND	ND	ND	ND	
O,P <sup>1</sup> - DDT $\mu\text{g/l}$	ND	ND	ND	ND	ND	
chlordane $\mu\text{g/l}$	ND	ND	ND	ND	ND	
dieldrin $\mu\text{g/l}$	ND	ND	ND	ND	ND	
endrin $\mu\text{g/l}$	ND	ND	ND	ND	ND	89.6% Recovery
P,P <sup>1</sup> - DDD $\mu\text{g/l}$	ND	ND	ND	ND	ND	
P,P <sup>1</sup> - DDT $\mu\text{g/l}$	ND	ND	ND	ND	ND	Methoxychlor - 100.0% Recovery
mirex $\mu\text{g/l}$	ND	ND	ND	ND	ND	
methoxychlor $\mu\text{g/l}$	ND	ND	ND	ND	ND	
toxaphene $\mu\text{g/l}$	ND	ND	ND	ND	ND	
Volume of Sample extracted $\mu\text{g/l}$	3240	3220	2760	3300	3050	
Total resolved Hydrocarbons by GC $\mu\text{g/l}$	416.63	259.98	ND	170.18	ND	

Appendix 1. Water current data of sites sampled during the winter and summer, 1983.

WINTER						SUMMER					
Station	Station Depth	Depth	Current Direction	Current Speed (knots)	Tide Phase	Station	Station Depth	Depth	Current Direction	Current Speed (knots)	Tide Phase
DS03	8.0	surface bottom	187° 170°	0.7 0.5	Ebb + 2:00 hrs.	DS03	8.5	surface bottom	012° 015°	0.7 0.4	Slack
DS06	8.0	surface bottom	160° 173°	1.0 0.8	Ebb + 4:30 hrs.	DS06	9.25	surface bottom	290° 110°	0.1 0.5	Ebb + 1:45 hrs.
DS09	9.25	surface bottom	150° 225°	0.9 0.7	Slack	DS08	9.25	surface bottom	160° 225°	0.8 0.4	Ebb + 4:50 hrs.
DS11	9.5	surface bottom	170° 285°	0.3 0.25	Flood + 1:30 hrs.	DS10	9.25	surface bottom	187° 160°	0.7 0.5	Slack
DS13	11.0	surface bottom	322° 305°	0.7 0.6	Flood + 3:05 hrs.	DS13	11.0	surface bottom	020° 010°	0.4 0.4	Slack
CS02	9.5	surface bottom	025° 295°	0.4 0.2	Slack	CS02	9.5	surface bottom	040° 340°	0.5 0.5	Slack
CS04	8.0	surface bottom	050° 155°	0.3 0.1	Ebb + 1:35 hrs.	CS05	7.75	surface bottom	092° 178°	0.2 0.1	Ebb + 2:45 hrs.
CS09	9.25	surface bottom	125° 150°	0.5 0.5	Ebb + 3:15 hrs.	CS09	10.0	surface bottom	147° 160°	0.5 0.4	Ebb + 4:40 hrs.
CS10	10.75	surface bottom	145° 155°	0.6 0.5	Ebb + 5:00 hrs.	CS11	10.25	surface bottom	110° 175°	0.4 0.2	Slack
CS13	11.0	surface bottom	125° 225°	0.3 0.1	Slack	CS13	10.5	surface bottom	020° 340°	1.1 0.7	Flood + 4:15 hrs.
DC03	6.5	surface bottom	350° 345°	0.2 0.3	Flood + 4:10 hrs.	DC03	7.5	surface bottom	090° 091°	0.4 0.4	Ebb + 2:35 hrs.
DC02	8.25	surface bottom	235° 190°	0.65 0.3	Slack	DC02	7.3	surface bottom	225° 230°	0.8 0.6	Slack
DC01	7.75	surface bottom	200° 170°	0.5 0.7	Ebb + 1:20 hrs.	DC01	9.5	surface bottom	107° 115°	0.7 0.3	Ebb + 4:00 hrs.



## Appendices

- Sokal, R.R. and F.J. Rohlf. 1982. Biometry. San Francisco, CA: W.H. Freeman Co. 776 p.
- South Carolina Wildlife and Marine Resources Dept. 1979. Benthic and sedimentologic studies on the Charleston Harbor ocean disposal area. Charleston Harbor deepening project. Report to the U.S. Army Corps. of Engineers, Charleston District. 193 p.
- South Carolina Wildlife and Marine Resources Dept. 1982. South Atlantic OCS Area Living Marine Resources Study, Year II. Vol. II: An investigation of live-bottom habitats off South Carolina and Georgia. Rept. to Minerals Management Service under contract AA551-CTL-18. 189 p.
- Stapor, F.W. and R.S. Murali. 1978. Computer modeling of littoral sand transport (shore-parallel) for coastal South Carolina. South Carolina Marine Resources Center Technical Report Number 29. 9 p.
- Theiling, D. 1983. Unpublished data. South Carolina Wildlife and Marine Resources, Fisheries statistics section.
- Theroux, R.B. and R.L. Wigley. 1983. Distribution and abundance of East Coast bivalve molluscs based on specimens in the National Marine Fisheries Service, Woods Hole Collection. NOAA Tech. Rept. NMFS SSRF-768. 172 p.
- U.S. Army Corps of Engineers. 1975. Cooper River diversion project, Charleston Harbor, South Carolina. Final Environmental Statement. U.S. Army Engineer District, Charleston. 201 p.
- U.S. Environmental Protection Agency. 1982. Draft Environmental Impact Statement for Savannah, GA., Charleston, S.C., and Wilmington, N.C. ocean dredged material disposal sites designation. Environmental Protection Agency, Criteria and Standards Division, Washington, D.C.
- U.S. Geological Survey Office of Marine Geology. 1979. Southeast Atlantic OCS geological studies. Final report F.Y. 1976. Bureau of Land Management, Wash., D.C.
- Van Dolah, R.F., D.R. Calder, and D.M. Knott. 1983. Assessment of benthic macrofauna in an ocean disposal area near Charleston, South Carolina. S.C. Marine Resources Center Technical Report Number 56. 97 p.
- Van Dolah, R.F., D.R. Calder, D.M. Knott, and M.S. MacIin. 1979. Effects of dredging and unconfined disposal of dredged material on macrobenthic communities in Sewee Bay, S.C. South Carolina Marine Resources Center Technical Report Number 39. 54 p.
- Van Name, W.G. 1945. The North and South American ascidians. Bulletin of the American Museum of Natural History 84:1-476.
- Wenner, C.A., C.A. Barans et al. 1980. Results of MARMAP otter trawl investigations in the South Atlantic Bight. V. Summer, 1975. South Carolina Marine Resources Center Technical Report Number 45. 57 p.
- Wenner, E.L., W.P. Coon, III. M.H. Shealy, Jr., and P.A. Sandifer. 1981. Species assemblages, distribution, and abundance of fishes and decapod crustaceans from the Winyah Bay estuarine system, S.C. South Carolina Sea Grant Consortium Technical Report No. 3. 61 p.
- Wenner, E.L., D.M. Knott, R.F. Van Dolah, and V.G. Burrell, Jr. 1983. Invertebrate communities associated with hard bottom habitats in the South Atlantic Bight. Estuarine, Coastal and Shelf Science 17: 143-158.
- Wenner, E.L., M.H. Shealy, Jr., and P.A. Sandifer. 1982. A profile of the fish and decapod crustacean community in a South Carolina estuarine system prior to flow alteration. National Oceanic and Atmospheric Administration Tech. Rept. NMFS SSRF-757. 17 p.
- Williams, A.B. 1965. Marine decapod crustaceans of the Carolinas. U.S. Fish and Wildlife Service, Fishery Bulletin 65: 1-298.
- Williams, W.T. and J.M. Lambert. 1961. Multivariate methods in plant ecology. III. Inverse association - analysis. Journal of Ecology 49: 717-729.
- Windom, H.L. 1972. Environmental aspects of dredging in estuaries. Journal of the Waterways, Harbors and Coastal Engineering Division WW4:475-487.
- Windom, H.L. 1973. Mercury distribution in estuarine-nearshore environment. Journal of the Waterways, Harbors and Coastal Engineering Division. WW2:257-264.
- Windom, H.L. 1976. Environmental aspects of dredging in the coastal zone. CRC Critical Review of Environmental Control 7:91-109.
- Windom, H.L. and R.G. Smith, Jr. 1972. Distribution of cadmium, cobalt, nickel and zinc in southeastern United States Continental Shelf waters. Deep-Sea Research 19: 727-730.
- Windom, H.L., F.E. Taylor, and E.M. Waiters. 1975. Possible influence of atmospheric transport on the total mercury content of southeastern Atlantic Continental Shelf surface waters. Deep-Sea Research 22:629-633.
- Winston, J.E. 1982. Marine bryozoans (Ectoprocta) of the Indian River Area (Florida). Bulletin of the American Museum of Natural History 173(2):99-176.

- McKee, J.E. and H.W. Wolf. 1963. Water Quality Criteria. Prepared by California Inst. of Technology for State Water Resources Control Board, Sacramento, CA. Rept. No. SWRCB-1.
- McKenzie, M.D., J.V. Miglarese, B.S. Anderson, and L.A. Barclay, eds. 1980. Ecological characterization of the Sea Island Coastal region of South Carolina and Georgia. Vol. II: Socioeconomic features of the characterization area. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-79/41. 321 p.
- Miller, G.C. and W.J. Richards. 1980. Reef fish habitat, faunal assemblages and factors determining distribution in the South Atlantic Bight. Proc. Gulf and Caribbean Fisheries Institute 32: 114-130.
- Minerals Management Service. 1983. Final environmental impact statement. Proposed 1983 Outer Continental Shelf Oil and Gas Lease Sale, offshore the South-Atlantic states, OCS Sale No. 78. U.S. Department of the Interior. New Orleans, LA.
- Moore, C.J., ed. 1980. A recreational guide to oystering, clamming, shrimping and crabbing in South Carolina. Recreational Fisheries, Office of Conservation, Management and Marketing, S.C. Wildlife and Marine Resources Department. 60 p.
- Morton, J.W. 1977. Ecological effects of dredging and dredge spoil disposal: A literature review. Technical Paper No. 94. U.S. Fish and Wildlife Service. 33 p.
- Myatt, D.O. 1978. The angler's guide to South Carolina artificial reefs. South Carolina Marine Resources Department. Office of Conservation and Management. Educational Report Number 9. 31 p.
- Parker, R.O., Jr., R.B. Stone, and C.C. Buchanan. 1979. Artificial reefs off Murrells Inlet, South Carolina. Marine Fisheries Review 41: 12-23.
- Pequenat, W.E., L.H. Pequegnat, B.M. James, E.A. Kennedy, R.R. Fay, and A.D. Fredericks. 1981. Procedural guide for designation surveys of ocean dredged material disposal sites. Final report prepared by TerEco Corp. for U.S. Army Engineer Waterways Experiment Station, Technical Report EL-81-1. 268 p.
- Pielou, E.C. 1975. Ecological Diversity. New York: John Wiley and Sons.
- Pilkey, O.H., F. Keer, and S. Keer. 1979. Surficial sediments of the U.S. Atlantic Southeastern United States continental shelf. pp. 138-181. In: South Atlantic Outer Continental Shelf Geological Studies Fiscal Year 1976: Geology.
- Plough, H.H. 1978. Sea squirts of the Atlantic continental shelf from Marine to Texas. John Hopkins Univ. Press. 118 p.
- Purvis, J.C. and H. Landers. 1973. South Carolina hurricanes or a descriptive listing of tropical cyclones that have affected South Carolina. S.C. Disaster Preparedness Agency, Columbia. 52 p.
- Riley, J.P. and D. Taylor. 1972. The concentrations of cadmium, copper, iron, manganese, molybdenum, nickel, vanadium and zinc in part of the tropical north-east Atlantic Ocean. Deep-Sea Research 19: 307-317.
- Saila, S.B., S.D. Pratt, and T.T. Polgar. 1972. Dredge spoil disposal in Rhode Island Sound. University of Rhode Island Marine Technical Report Number 2. 48 p.
- Sandifer, P.A., J.V. Miglarese, D.R. Calder, et al. 1980. Ecological characterization of the Sea Island coastal region of South Carolina and Georgia. Vol. III: Biological features of the characterization area. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-79/42. 620 p.
- Science Applications, Inc. 1981a. South Atlantic OCS Physical Oceanography. Final progress report. Volume II: Technical Report. Prepared for Bureau of Land Management. 354 p.
- Science Applications, Inc. 1981b. South Atlantic OCS Physical Oceanography. Final progress report. Volume III: Data Products, Parts 1 and 2. Prepared for Bureau of Land Management. 378 p. and 248 p.
- Science Applications, Inc. 1983a. South Atlantic OCS Physical Oceanography. Final progress report. Volume I: Executive Summary. Prepared for Minerals Management Service. 10 p.
- Science Applications, Inc. 1983b. South Atlantic OCS Physical Oceanography. Final progress report. Volume II: Technical Report. Prepared for Minerals Management Service. 300 p.
- Shealy, M.H. 1974. Bottom trawl data from South Carolina Estuarine Survey cruises 1973. South Carolina Marine Resources Research Institute Data Report Number 1. 113 p.
- Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. New York: McGraw-Hill. 312 p.
- Smith, T.I.J., D.E. Marchette, and R.A. Smiley. 1982. Life history, ecology, culture and management of the Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus* Mitchell, in South Carolina. South Carolina Wildlife and Marine Resources Department Final Technical Report. U.S. Fish and Wildlife Service Project No. AFS-9. 75 p.
- Smith, T.I.J., D.E. Marchette, and G.F. Ulrich. 1984. The Atlantic sturgeon fishery in South Carolina. North American Journal of Fisheries Management 4:164-176.

- Harris, J., J. M. J. J. J., and A. G. Altschaeff. 1971. Sediments of lower Chesapeake Bay, with emphasis on mass properties. *Journal of Sedimentary Petrology* 41(4):727-755.
- Harris, J. M. J. J. 1976. Studies on bivalve molluscs of the genus *Trassineilla* in the North-western Gulf of Mexico: anatomy, ecology, and systematics. Texas University Publication Institute Marine Science 11: 65-89.
- Henry, G. J., and R. T. Miles. 1979. Distribution and occurrence of reefs and hard bottoms in the Georgia Bight. in: South Atlantic Outer Continental Shelf Geological Studies, Fiscal Year 1976: Geology. USGS Final Report prepared for Bureau of Land Management, Washington, D.C. pp. 324-381.
- Hinde, J. M., J. M. J. J., Smith, and D. R. Calder. 1961. Benthic and nektonic studies of Winyah Bay for the proposed channel deepening project and dredging of the western channel turning basin. U.S. Army Corps of Engineers Contract Report #DAW60-80-C-0029, 141 p.
- Hoese, H. D. 1973. A trawl study of nearshore fishes and invertebrates of the Georgia coast. *Contrib. Marine Science* 17:63-98.
- Holmes, J. W., E. A. Slade, and C. J. McLerran. 1974. Migration and redistribution of zinc and cadmium in marine estuarine system. *Environmental Science and Technology* 8: 255-259.
- Hopkins, S. R. and T. M. Murphy. 1981. Reproductive ecology of *Caretta caretta* in South Carolina. S.C. Wildlife and Marine Resources Dept. Division of Wildlife and Freshwater Fisheries. Project No. E-1, Study No. VI-A1. 96 p.
- Johnson, F. A. 1970. A reconnaissance of the Winyah Bay estuarine zone, South Carolina. U.S. Geological Survey, Water Resources Division in cooperation with S.C. Water Resources Commission. 36 p.
- Jones, Edmunds and Associates, Inc. 1979a. Results of bioassay evaluation of Charleston Harbor sediments C1-C13. Final report to: Dept. of Army, Charleston District Corps of Engineers. 84 p.
- Jones, Edmunds and Associates, Inc. 1979b. Results of bioassay evaluation of Charleston Harbor sediments C14-C17. Final report to: Dept. of Army, Charleston District Corps of Engineers. 84 p.
- Jones, Edmunds and Associates, Inc. 1979c. Results of bioassay evaluation from Georgetown Harbor channel. Final report to: Dept. of Army, Charleston District Corps of Engineers. 33 p.
- Keiser, R. K. 1977. The incidental catch from commercial shrimp trawlers of the South Atlantic states. South Carolina Marine Resources Center Technical Report Number 26. 38 p.
- Knott, D. M., D. R. Calder, and R. F. Van Dolah. 1983a. Macrobenthos of sandy beach and nearshore environments at Murrells Inlet, South Carolina, U.S.A. *Estuarine, Coastal and Shelf Science* 16:573-590.
- Knott, D. M., R. F. Van Dolah, and D. R. Calder. 1983b. Ecological effects of rubble weir jetty construction at Murrells Inlet, South Carolina. Vol. II: Changes in macrobenthic communities of sandy beach and nearshore environments. Prepared for Dept. of the Army, Coastal Engineering Research Center. 91 p.
- Lance, G. N. and W. T. Williams. 1967. A general theory of classificatory sorting strategies. I. Hierarchical systems. *Comput. J.* 9:373-380.
- Leland, J. G. 1968. A survey of the sturgeon fishery of South Carolina. Bears Bluff Laboratories No. 47. 27 p.
- Lonsdale, D. J. and B. C. Coull. 1977. Composition and seasonality of zooplankton of North Inlet, South Carolina. *Chesapeake Science* 18(3):272-283.
- Margalef, D. R. 1958. Information theory in ecology. *Gen. Syst.* 3:36-71.
- Mathews, T. D. and O. Pashuk. 1977. A description of oceanographic conditions off the south-eastern United States during 1973. South Carolina Marine Resources Center Technical Report Number 19. 105 p.
- Mathews, T. D. and O. Pashuk. 1982. A description of oceanographic conditions of the south-eastern United States during 1974. South Carolina Marine Resources Center Technical Report Number 50. 114 p.
- Mathews, T. D. and O. Pashuk. 1984. Shelf response to the cold winters of 1977 and 1978 in the South Atlantic Bight (SAB)\*. *Litoralia*: (in press).
- Mathews, T. D. and M. H. Shealy, Jr. 1978. Hydrography of South Carolina estuaries, with emphasis on the North and South Edisto and Cooper Rivers. South Carolina Marine Resources Center Technical Report Number 30. 142 p.
- Mathews, T. D., M. H. Shealy, Jr., and N. Cummings. 1981. Hydrography of South Carolina estuaries, with emphasis on the North and South Santee and Charleston Harbor - Cooper River estuaries. South Carolina Marine Resources Center Technical Report Number 47. 128 p.
- Mathews, T. D. and M. H. Shealy, Jr. 1982. A description of the salinity regimes of major South Carolina estuaries. South Carolina Marine Resources Center Technical Report Number 50. 114 p.
- Mathews, T. D., F. W. Stapor, Jr., C. R. Richter, et al., eds. 1980. Ecological characterization of the Sea Island coastal region of South Carolina and Georgia. Vol. I: Physical features of the characterization area. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-79/40. 212 p.

Appendix 3. Overall ranked abundance of macroinvertebrates collected during winter at the control site. Mean density (number per 0.1 m<sup>2</sup>) and standard error of the mean at each station is indicated.

RANK	SPECIES	CS02			CS04			CS09			CS10			CS13		
		MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR
1	ENSIIS DIRECTUS	64.0	12.1	6.9	23.4	6.4	3.7	10.8	3.0	3.7	40.4	5.4	43.2	10.9		
2	CRASSINELLA LUNULATA	7.4	1.0	3.8	6.4	0.4	3.0	12.4	4.8	3.0	17.2	2.3	46.2	17.8		
3	BATEA CATHARTINENSIS	2.8	0.4	0.4	0.4	0.4	0.4	4.8	1.7	2.8	17.2	2.3	1.0	1.0		
4	ERICHONIA BRASILIENSIS	30.2	9.5	1.2	4.8	1.2	1.2	3.6	1.7	4.1	67.2	28.8	4.0	1.0		
5	POLYDORA CAECA	0.4	0.2	0.4	4.8	1.2	1.2	13.4	6.4	3.6	16.4	3.6	5.8	2.0		
6	NEMATODA	1.6	0.6	1.5	3.4	1.5	1.5	7.2	1.3	0.4	13.4	4.9	12.8	5.4		
7	CRASSINELLA MARTINICENSIS	4.4	1.7	1.2	3.4	1.5	1.2	7.2	1.3	0.4	21.4	4.9	36.8	19.1		
8	NEMERTINEA	..	..	..	32.6	7.2	7.2	0.6	0.4	0.4	29.4	6.7	1.0	0.7		
9	ASPIDOSIPHON GOSNOLDI	0.8	0.4	0.4	1.2	0.4	0.4	0.6	0.7	0.4	16.4	3.8	0.6	0.4		
10	EXOGONE DISPAR	1.8	0.9	0.5	2.8	0.5	0.5	2.6	0.6	0.6	17.6	7.3	6.4	4.5		
11	METHARPINIA FLORIDANA	0.6	0.6	0.6	4.4	0.4	0.4	0.8	0.4	0.4	20.4	7.5	3.2	1.1		
12	METHARPINIA CALIFORNIENSIS	0.4	0.4	0.4	1.4	0.4	0.4	0.8	0.4	0.4	17.4	3.6	1.2	0.6		
13	NEREIS FALSA	0.4	0.4	0.4	1.4	0.4	0.4	0.8	0.4	0.4	17.4	3.6	1.2	0.6		
14	AMPHICUTIA PULCHRELLA	0.4	0.4	0.4	1.4	0.4	0.4	0.8	0.4	0.4	17.4	3.6	1.2	0.6		
15	OXYCOCYSTYLIS SMITHI	1.8	0.4	1.8	2.4	0.4	1.8	0.8	0.4	0.4	3.8	1.9	10.2	2.5		
16	ULIGOCHAETA	0.4	0.2	0.2	8.2	0.4	0.4	0.6	0.4	0.4	0.2	10.2	10.2	6.3		
17	HYDRA VITATA	0.4	0.2	0.2	2.6	0.4	0.4	0.4	0.4	0.4	17.2	5.4	10.2	6.3		
18	NEREIS	3.0	1.4	0.7	2.6	0.4	0.4	0.4	0.4	0.4	17.2	5.4	10.2	6.3		
19	UNCITOLA SERKATA	6.2	1.3	0.2	2.6	0.4	0.4	1.2	1.2	1.6	8.0	1.6	1.8	1.0		
20	PAGURUS HENDERSONI	1.8	1.3	0.8	0.2	0.2	0.2	0.2	1.2	1.6	11.2	3.3	..	..		
21	ELASMORUS LEVINS	2.0	1.3	1.3	1.4	0.4	0.4	0.6	0.4	0.4	13.2	4.5	0.2	0.2		
22	EPIZANTHUS AMERICANUS	1.8	0.6	0.6	1.4	0.4	0.4	0.6	0.4	0.4	13.2	4.5	0.2	0.2		
23	SABELLARIA VULGARIS	0.6	0.6	0.6	0.8	0.4	0.4	0.6	0.4	0.4	13.2	4.5	0.2	0.2		
24	SPIOPLANES BUBBAX	1.8	0.6	0.6	0.8	0.4	0.4	0.6	0.4	0.4	13.2	4.5	0.2	0.2		
25	HEMIPOLYS ELONGATA	1.8	0.6	0.6	0.8	0.4	0.4	0.6	0.4	0.4	13.2	4.5	0.2	0.2		
26	CREPIS LAMELLATA	1.8	0.6	0.6	0.8	0.4	0.4	0.6	0.4	0.4	13.2	4.5	0.2	0.2		
27	NEREIS SUCCINEA	2.2	1.5	0.2	0.4	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
28	NEREIS SUCCINEA	1.2	0.7	0.2	0.4	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
29	INVERTEBRATA	1.2	0.7	0.2	0.4	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
30	INVERTEBRATA	1.2	0.7	0.2	0.4	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
31	INVERTEBRATA	1.2	0.7	0.2	0.4	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
32	BRANIA CLAVATA	0.2	0.2	0.2	1.6	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
33	ASTYRIS LUNATA	0.2	0.2	0.2	1.6	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
34	GLYCERA SP. A	0.2	0.2	0.2	1.6	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
35	UPHROIDEA	0.2	0.2	0.2	1.6	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
36	ACANTHOPHAGUS MILLSI	1.2	0.8	0.4	1.2	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
37	AUTOLYUS SP.	1.2	0.8	0.4	1.2	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
38	NEPHYTIS PICTA	2.0	0.7	0.7	1.4	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
39	DIOPATHA CUPREA	0.8	0.5	0.5	1.4	0.4	0.4	0.4	0.4	0.4	13.2	4.5	0.2	0.2		
40	POLYDORA EXIMIUS	2.0	1.0	1.1	3.4	0.8	2.2	1.8	1.0	1.6	2.0	1.5	0.4	0.2		
41	POLYDORA CAECA	3.0	1.3	0.7	1.8	0.8	1.1	1.8	0.7	0.2	2.0	1.5	0.4	0.2		
42	NUCULA PROXIMA	..	..	..	0.2	0.2	0.2	0.2	0.2	0.2	2.0	1.5	0.4	0.2		
43	HAMANTIA GOODEI	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	2.0	1.5	0.4	0.2		
44	NOTOCIRRUS SPINIFERUS	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	2.0	1.5	0.4	0.2		
45	LEMBOS SMITHI	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	2.0	1.5	0.4	0.2		
46	EULALIA SANGUINEA	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	2.0	1.5	0.4	0.2		
47	EULALIA SANGUINEA	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	2.0	1.5	0.4	0.2		
48	PERINICOLA SP. GLADIFORMIS	0.6	0.4	0.4	1.6	0.4	0.4	0.4	0.4	0.4	2.0	1.5	0.4	0.2		
49	NEPHYTIS PICTA	0.6	0.4	0.4	1.6	0.4	0.4	0.4	0.4	0.4	2.0	1.5	0.4	0.2		
50	GLYCERA DIBRANCHIATA	2.6	1.5	0.4	1.6	0.4	0.4	0.4	0.4	0.4	2.0	1.5	0.4	0.2		
51	PISTIA GUADALUPATA	0.8	0.4	0.4	1.6	0.4	0.4	0.4	0.4	0.4	2.0	1.5	0.4	0.2		
52	AUTOMATE EVERMANNI	0.6	0.4	0.4	0.6	0.4	0.4	0.4	0.4	0.4	2.0	1.5	0.4	0.2		
53	TURBELLARIA	..	..	..	0.2	0.2	0.2	0.2	0.2	0.2	2.0	1.5	0.4	0.2		
54	GONIAIDES CAHOLINAE	..	..	..	0.2	0.2	0.2	0.2	0.2	0.2	2.0	1.5	0.4	0.2		
55	AMELENA TRILOBATA	..	..	..	0.2	0.2	0.2	0.2	0.2	0.2	2.0	1.5	0.4	0.2		
56	ANCISTROSOMUS HARTMANAE	..	..	..	0.2	0.2	0.2	0.2	0.2	0.2	2.0	1.5	0.4	0.2		
57	SPIO FETIDIGNEAE	0.6	0.2	0.2	0.4	0.4	0.4	0.4	0.4	0.4	2.0	1.5	0.4	0.2		
58	CIRRA TULLIAE	..	..	..	0.4	0.4	0.4	0.4	0.4	0.4	2.0	1.5	0.4	0.2		
59	AMPELISCUS VACUUM	..	..	..	0.4	0.4	0.4	0.4	0.4	0.4	2.0	1.5	0.4	0.2		
60	AMPELISCUS SP. A	..	..	..	0.4	0.4	0.4	0.4	0.4	0.4	2.0	1.5	0.4	0.2		
61	SPIOPLANES SP. A	..	..	..	0.4	0.4	0.4	0.4	0.4	0.4	2.0	1.5	0.4	0.2		
62	CIRROLANA POLITA	..	..	..	1.2	0.4	0.4	0.8	0.2	0.2	1.0	1.0	0.6	0.6		

Appendix 5. (Continued)

RANK	SPECIES	CS02			CS04			CS09			CS10			CS13		
		MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR
62	PARACAPPELLA TENUIS	0.2		0.2	0.2		0.2				2.8		1.6	1.8		0.7
66	PELECYPODA H				0.2		0.2				0.6		0.6			
66	PAGURUS SP.	0.2		0.2	0.2		0.2	0.4	0.4	0.4	2.0		2.0	0.4		0.2
66	ACTINARIA				0.2		0.2	0.2	0.2	0.2	1.0		1.0	0.4		0.2
66	MALDANIDAE				0.2		0.2	0.2	0.2	0.2	1.4		1.2	0.8		0.4
69	PARVILUCINA MULTILINEATA										1.8		1.0	0.8		0.2
69	ARCIDAE A	0.4		0.2	1.6		1.4	0.4	0.4	0.5	2.4		0.5	0.2		0.2
69	SPHAEROSYLLIS ACICULATA	0.2		0.2												
69	UMENIA FUSIFORMIS	2.2		1.3							2.0		0.4	0.2		
74	PAGURUS CAROLINENSIS				0.2		0.2				1.4		0.9	0.8		0.2
74	THARYX MARIONI										1.4		0.7	0.8		0.2
74	THARYX SP.										1.6		1.0	2.0		0.8
74	ARMANCIA MACULATA										0.6		0.4	1.8		0.7
74	THARYX ANNULOSUS										1.0		0.8	1.0		0.6
77	MUSCULUS LATEHALIS	0.4		0.4							1.2		0.6	0.6		0.4
77	CIRRORHOPUS LYRIFORMIS										1.6		1.1	0.4		0.2
81	HEXAPANOPEUS ANGUSTIFRONS	0.2		0.2							0.6		0.4	0.4		0.2
81	NEOPANOPE SAYI										1.8		1.0	1.8		0.7
81	MELANELLA SP. B										0.6		0.4	1.0		0.6
81	SYLLEPTIDAE	0.2		0.2							1.0		0.8	0.6		0.4
81	TEREBELLIDAE	0.6		0.4							1.2		0.6	0.6		0.4
81	PHILOSPIO CIRRIFERA										1.6		1.1	0.4		0.2
87	LUCORACTIA INCERTA	0.2		0.2							0.6		0.4	0.4		0.2
87	LEMBOS SP.										1.0		0.3			
87	NATICA PUSILLA										1.0		0.5			
87	LITHOPHAGA EISULCATA	0.2		0.2	1.6		1.1	0.4	0.4	0.2	1.0		0.7			
87	PRIONOSPION FALLAX										1.0		0.5			
87	SPION SP. A	0.4		0.2							1.4		0.7			
93	EOHRHOLGUS SPINOSUS															
93	PARAMETOPHELLA CYPRI															
93	TIRON TROPACTIS															
93	NUDIBRANCHIA	0.2		0.2	0.8		0.6	0.4	0.4	0.4	0.4		0.4	1.4		0.7
93	PELECYPODA B	0.4		0.4	0.6		0.2				1.4		0.5			
93	ODONTOSTELLIS FULGURANS										1.0		0.3			
99	CANCER THORACATUS				0.2		0.2	0.2	0.2	0.2	1.4		0.5			
99	UNCIOLEA SP.				0.2		0.2	0.2	0.2	0.2	1.0		0.5			
99	ASPIDOSIPHON ALBUS				0.8		0.4	0.6	0.6	0.6	1.4		0.7			
99	MAGELONA PHYLLISAE	0.6		0.6	0.2		0.4	0.6	0.6	0.6	1.4		0.7			
99	PARAGNATHAE															
99	SIGAMBRA HASSI				0.2		0.2	0.6	0.6	0.6	0.4		0.4	0.8		0.4
106	OSTRACODA				0.2		0.2				0.4		0.4	0.8		0.4
106	GASTROPODA				0.2		0.2				0.6		0.6	0.8		0.4
106	PLEURONERIS TRIDENTATA	0.4		0.4	0.4		0.4							0.6		0.4
106	SPHAERODOROPSIS SP. A													0.6		0.4
106	UNIPHIS NEBULOSA				0.4		0.4	0.2	0.2	0.2	0.8		0.5	0.4		0.2
106	PSEUDOLYTHOE AMBIGUA										0.6		0.4	0.4		0.2
106	SCHOLEPIS SQUAMATA										0.8		0.4	0.8		0.4
106	SCHISTOMERINGS RUDOLPHI	0.2		0.2							0.8		0.6	0.8		0.4
119	EUCERAMUS PRAELONGUS										0.8		0.6	0.8		0.4
119	PINNIXA CYLINDRICA										0.2		0.2	0.2		0.2
119	LISTRIELLA BARNARDI				0.4		0.2				0.8		0.6	0.6		0.4
119	PELECYPODA										0.8		0.6	0.8		0.4
119	LYONSIA HYALINA										0.8		0.6	0.8		0.4
119	PHOLADIDAE A										0.8		0.6	0.8		0.4
119	SPINACULIDA				0.4		0.2	0.2	0.2	0.2	0.8		0.5	0.8		0.4
119	OPHELIA DENTICULATA				0.4		0.2				0.8		0.5	0.8		0.4
119	SPHAERODOROPSIS				0.8		0.4				0.8		0.5	0.8		0.4
119	PHERUSIA EHLEPSI				0.4		0.2				0.8		0.5	0.8		0.4
119	ANCISTROSYLLIS SP.	0.2		0.2	0.4		0.2				0.8		0.5	0.8		0.4
119	LOIMIA MEDUSA				0.4		0.2				0.8		0.5	0.8		0.4
119	SIGAMBRA TENTACULATA				0.4		0.2	0.2	0.2	0.2	0.8		0.5	0.8		0.4
119	SPIONIDAE										0.4		0.4	0.8		0.4

Appendix 5. (Continued)

RANK	SPECIES	CS02				CS04				CS09				CS10				CS13			
		MEAN	ST	ERR		MEAN	ST	ERR		MEAN	ST	ERR		MEAN	ST	ERR		MEAN	ST	ERR	
119	NESTIONIDAE	0.4		0.2		0.2		0.2		0.4		0.4		0.2		0.2					
119	CAULLERIELLA KILLARIENSIS					0.2		0.2						0.2		0.2					
119	SAHELLA MICROPHALMA					0.2		0.2						0.2		0.2					
135	LILYBORGIA SP. A													0.8		0.6		0.6		0.4	
135	PHOTIS SP.									0.2		0.2		0.6		0.6		0.2		0.2	
135	PHOTIS PUGNATOR													0.6		0.6		0.4		0.2	
135	CUMACEA					0.2		0.2						0.6		0.4					
135	MELLITA QUINGUESPERFORATA													0.6		0.4		0.2		0.2	
135	INVERTEBRATA C													0.6		0.4					
135	EPILICENTRICA																				
135	ARRAENA AQUALIS																				
135	MELANELLA					0.4		0.4													
135	POLYCHAETA					0.2		0.2						0.2		0.2		0.2		0.2	
135	PISTA CRISTATA					0.2		0.2						0.2		0.2		0.2		0.2	
135	ORILONEHEIS MAGNA					0.2		0.2						0.2		0.2		0.2		0.2	
135	URRINIIDAE					0.2		0.2						0.6		0.2					
135	CERATOCERPALE SP. A													0.6		0.2					
135	POLYNOIDAE A					0.2		0.2						0.4		0.2					
135	BRANCHIOSTOMA CARIBAEUM									0.2		0.2		0.4		0.2					
158	HYPOCONCHA ARCUATA													0.4		0.2					
158	PARAHAUSTORIUS LONGIMERUS													0.2		0.2		0.2		0.4	
158	MUTILEMBOIDES NAGELI													0.4		0.2		0.4		0.4	
158	MYCILIPSUS BIGELOWI													0.4		0.4					
158	SIENOTHODES SP.													0.4		0.4					
158	PARAPLEUSTES AESTUARIUS													0.4		0.4					
158	EUDEVENOPUS HONGURANUS													0.4		0.4					
158	GLOTTIDIA PYRAMIDATA													0.2		0.2		0.4		0.2	
158	TELLINA TEXANA													0.2		0.2		0.2		0.2	
158	PELECYPODA S													0.2		0.2		0.2		0.2	
158	MYTILIDAE A													0.2		0.2		0.2		0.2	
158	UDOSTOMIA SP. A					0.2		0.2						0.2		0.2					
158	ECHLURIDA													0.4		0.2					
158	HYDROIDES UNCINATA													0.2		0.2		0.2		0.2	
158	PRIONOSPION SP.													0.4		0.2		0.2		0.2	
158	CHALIFORMIA GRANDIS													0.4		0.2		0.2		0.2	
158	ORBINIA AMERICANA													0.4		0.2		0.2		0.2	
158	NEREIS ACUMINATA													0.4		0.2		0.2		0.2	
158	SCOLGLOS RUBRA													0.4		0.4		0.2		0.2	
158	LUMBRINERIS LATREILLI									0.4		0.2		0.4		0.4		0.2		0.2	
158	ARMANDIA AGILIS													0.4		0.2		0.4		0.2	
158	ARICIDEA SUECICA													0.4		0.2		0.4		0.2	
158	LUMBRINERIS TENUI													0.4		0.2		0.4		0.2	
158	POLYDORA PERSTERI													0.4		0.2		0.4		0.2	
158	HAPOSCOLOPLOS FRAGILIS													0.4		0.2		0.4		0.2	
158	CAEULELLIDAE	0.4		0.4										0.4		0.2		0.2		0.2	
158	NESTIONIDAE A	0.2		0.2										0.4		0.2					
158	SAPRELLIDAE	0.2		0.2										0.4		0.2					
158	POLYDORA	0.2		0.2										0.4		0.2					
158	CHAETOPTERICHAE	0.2		0.2										0.4		0.2					
222	PAGURUS LONGICARPUS													0.2		0.2					
222	UVALIPES STEPHENSONI									0.2		0.2		0.2		0.2		0.2		0.2	
222	PORUNUS GIRRESII													0.2		0.2					
222	NANOPLAX XANTHIIFORMIS													0.2		0.2		0.2		0.2	
222	MISSODACTYLUS MELLITAE													0.2		0.2		0.2		0.2	
222	MITROPHARYX BICORNUTUS													0.2		0.2		0.2		0.2	
222	MITROCHRYPTA GRANULATA													0.2		0.2		0.2		0.2	
222	AGGURIDEA													0.2		0.2		0.2		0.2	
222	HIPPOLYTE													0.2		0.2		0.2		0.2	
222	ACANTHOHAUSTORIUS SP.									0.2		0.2		0.2		0.2		0.2		0.2	
222	SYNCHELIOTIUM AMERICANUM													0.2		0.2		0.2		0.2	
222	MUTILEMBOIDES SP.													0.2		0.2		0.2		0.2	

Appendix 5. (Continued)

RANK	SPECIES	CS02			CS04			CS09			CS10			CS13		
		MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR
222	MAEHA CAHOLINIANA	.	.	.	0.2	0.2	.	.	.	.	0.2	0.2	.	.	.	.
222	CYCLAPUS TUBULATIS	0.2	0.2	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	NEOMYSIS AMERICANA	0.2	0.2	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	ACANTHOHAUSTORIUS SHOEMAKERI	.	.	.	.	.	0.2	0.2	.	.	0.2	0.2	.	.	.	.
222	CAPRELLA PENANTIS	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	MELITA APPENDICULATA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	AMPHILOCHIDAE	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	TIRON TRIOCCELLATUS	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	AMPHIPODA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	AMPHIPODA E	0.2	0.2	.	0.2	0.2	.	.	.	.	.	.	.	0.2	0.2	.
222	ANOPLODACTYLUS PETIOLATUS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
222	AFNILLA RENIFORMIS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
222	ASTERIAS FORBESII	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	HEMICHORDATA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	PHORONIS ARCHITECTA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	INVERTEBRATA F	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	INVERTEBRATA H	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	NUDIBRANCHIA C	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	ULIVELLA MUTICA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	CONRULA BARRATTIANA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	PARVANACHIS OBESA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	ANOMIA SIMPLEX	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	TELLINA AEGUISTRIATA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	SETLLA ADAMSI	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	PELECYPODA T	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	UORIDELLA BURCHI	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	MODIOLUS MODIOLUS	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	EPTIGNIUM SP. A	0.2	0.2	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	MITHELLA SP. A	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	ACTECCINA CANALICULATA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	TURBONILLA SP. C	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	TEREBRA CONCAVA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	TURRIDAE H	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	MARGINELLA GUTTATA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	SCAPHOPODA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	PARADENTALIUM SP. A	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	CULUS SP. A	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	SIPUNCULIDA A	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	DRILONEHEIS SP.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	SEPIULA VERMICULARIS GRANULOSA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	SEPIULA VERMICULARIS	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	MAGELMA SP. A	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	NOTOMASTUS AMERICANUS	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	STHENELEIS SP.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	HAMMOTHOE SP.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	CERATONHEIS SP. A	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	HYDRGIDES SP. A	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	LUMBRINERIDAE	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	FILOGRANA IMPLEXA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	PARAPIONOSYLLIS SP. A	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	PARAPIONOSYLLIS SP. A	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	ACROCIIRIDAE	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	DOBVILLEIDAE	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	CIRRIFORMIA SP.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	SIGAMERA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	SIGAMERIS BOA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	NOTOMASTUS LATERICUS	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	HYDROSTES PROTULICOLA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	SPIOCETOPTERUS COSTARUM	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.
222	PHYLLODOCE MUCOSA	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.





Appendix 6. Overall ranked abundance of macroinvertebrates collected during summer at the control site. Mean density (number per 0.1 m<sup>2</sup>) and standard error of the mean at each station is indicated.

CONTROL AREA, SUMMER SAMPLES

RANK	SPECIES	CS02			CS05			CS09			CS11			CS13		
		MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR
1	NEMATODA	0.6		0.4	2.2		1.0	0.4		2.3	4.0		0.9	38.2		8.3
2	MEDICPASTUS CALIFORNIENSIS	16.6		5.5	0.8		0.8	0.8		0.4	10.2		3.9	15.2		3.3
3	ENSIS DIRECTUS				0.2		0.2	0.2		0.4	13.0		4.4	15.0		5.2
5	CUPULADRIA DOMA				0.4		0.4	0.4		3.9	11.4		0.2	17.6		1.8
5	GRASSINELLA LUNULATA				0.6		0.6	0.6		2.5	11.8		0.2	15.0		1.5
5	PARAFRITONOSPION PINNATA	33.0		9.5	28.0		5.7	1.4		1.2	0.6		0.6	0.2		0.2
7	HYDRA VITTATA				0.0		0.0	0.0		0.0	1.0		0.6	2.0		2.4
8	GRASSINELLA MARTINICENSIS	0.2		0.2	1.0		0.5	1.4		1.5	0.6		0.2	4.4		2.2
9	ULIGONELLA	4.2		1.5	5.6		2.0	0.8		0.5	3.4		0.2	4.4		1.8
10	AMPHIOLOCA PULCHELLA				4.6		1.4	0.6		0.6	0.6		0.2	2.6		3.6
11	AMALANA TRILOBATA				0.2		0.2	0.8		0.8	0.0		0.5	2.6		0.9
12	BATEA CATHARTINENSIS	2.8		2.3	0.2		0.3	0.0		0.4	0.8		1.1	2.0		1.0
14	NEMERTINEA CAROLINAE				3.0		0.9	0.6		0.5	2.4		0.4	6.8		1.2
15	GONIACTIPHON GOSNOLDI				4.2		1.3	0.2		0.8	1.6		0.4	8.4		3.7
16	ANCISTROSYLLIS HARTMANAE				0.4		0.4	1.0		0.5	1.0		0.5	9.2		1.7
17	PAGURUS HENDERSONI	0.4		0.4	0.4		0.4	3.2		2.0	0.8		0.4	6.4		3.9
17	POLYCHORDILDAE A				0.2		0.2	0.2		0.2	1.0		0.5	9.2		1.9
19	EULALIA SANGUINEA				0.2		0.2	0.2		0.2	0.8		0.4	6.4		0.4
20	EUCHITHONUS BRASILIENSIS							0.2		0.2	7.2		0.4	0.6		1.4
21	DISCOPHELIA URBELLATA				5.2		1.6	0.2		0.2	0.6		0.4	0.6		1.4
22	SABELLIA SP.	0.4		0.2	2.0		0.7	0.2		0.2	0.4		0.4	1.0		1.1
23	CIRRHOPORUS LYRIFORMIS	0.2		0.2	1.0		0.5	1.4		0.7	0.6		0.6	1.8		1.0
26	AUTOPATE EVERMANNI	5.4		5.4	1.0		0.8	0.6		0.4	1.8		0.6	1.8		1.1
26	NUCULA PROXIMA	1.8		0.4	1.6		0.4	0.6		0.2	0.8		0.5	0.6		3.5
26	CHEPICULA FORNICATA	2.0		2.0				0.6		0.2	0.2		0.4	5.2		0.2
29	COROPHIUM SP. C							0.6		0.2	3.2		0.4	0.0		0.9
29	POLYCIRRUS EXIMIUS				0.4		0.4	0.2		0.4	0.6		0.7	4.0		0.6
31	MYSIDOPSIS BIGELOWI				0.2		0.2	1.4		0.4	1.4		0.9	4.0		0.4
32	SPIOPHONES BOMBYX	0.4		0.2	0.4		0.4	0.4		0.3	2.6		0.4	0.0		1.1
34	OWENIA FUSIFORMIS				3.0		1.1	1.0		0.4	0.8		0.4	2.0		1.4
36	GLYCERA DIABRANCHIATA				0.2		0.2	0.4		0.4	0.6		0.4	2.4		1.0
36	METHARPIA FLUIDANA				0.2		0.2	0.4		0.4	3.2		1.9	1.0		0.9
36	THORAX THIOCELLATUS										0.4		0.2	1.0		0.5
36	THORAX ANNULOSUS										0.4		1.9			
40	EUCERAMUS PRAELONGUS	0.2		0.2	0.6		0.4				3.2		0.7	1.0		0.9
40	PINNIXA RETINENS				0.2		0.4	1.4		0.5	0.4		0.2	3.0		1.8
40	PELECYPODA H										1.2		0.7	1.0		0.5
40	PARAPIGONOSYLLIS SP. A				0.6		0.4	1.4		0.5	2.4		1.6			
44	NEPHYS PICTA	3.0		1.3	0.2		0.4	1.0		0.6	0.8		0.4	0.2		0.2
44	CUPHULA BARRATTIANA				0.6		0.4	1.0		0.6	0.8		0.4	0.2		0.2
44	PELECYPODA U				1.0		0.8	0.8		0.6	0.8		0.4	0.2		0.2
46	HEMIPODUS ROSEUS	0.6		0.4	0.4		0.4	0.8		0.6	0.8		0.4	0.2		0.2
46	ACTINIA				0.4		0.4	0.8		0.6	0.8		0.4	0.2		0.2
46	GLYCERA SP. A				0.4		0.4	0.8		0.6	0.8		0.4	0.2		0.2
50	UNCIOLOA SERRATA	0.4		0.2	1.0		0.3	0.8		0.6	0.8		0.4	0.2		0.2
50	EUCERAMUS HONDURANUS	0.2		0.2	0.4		0.4	0.8		0.6	0.8		0.4	0.2		0.2
50	PSEUDOSYTHOE AMBIGUA	0.4		0.2	1.0		0.3	0.8		0.6	0.8		0.4	0.2		0.2
50	PHILONOSPION CIRRIFERA							0.8		0.6	0.8		0.4	0.2		0.2
53	LUMBRINERIS TENUI							1.4		0.2	0.8		0.4	0.2		0.2
53	HAMANIA GOODEI							0.4		0.2	0.8		0.4	0.2		0.2
55	THACHYPNEAUS CONSTRICTUS	0.4		0.2	0.2		0.2	0.4		0.4	0.8		0.4	0.2		0.2
55	MALDANIDAE SERRATORHITA	0.2		0.2	0.2		0.2	0.4		0.4	0.8		0.4	0.2		0.2
59	LEPTOCHELA VACUUM	0.2		0.2	0.2		0.2	0.4		0.4	0.8		0.4	0.2		0.2
59	INVERTEBRATA D	0.2		0.2	0.2		0.2	1.0		0.3	0.8		0.4	0.2		0.2
59	MAGELCNA SP. C	1.8		1.2	1.8		0.2				1.2		0.8	0.2		0.2
59	DIOPATRA PARVA	0.6		0.2	1.8		0.2				1.0		0.8	0.2		0.2

Appendix 6. (Continued)

RANK	SPECIES	CS02			CS05			CS09			CS11			CS13		
		MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR
65	CERAPUS TURULARIS	0.4	0.2	0.2	.	.	.	.	.	.	1.2	1.2	0.2	0.2	0.2	0.2
65	SPITOPHANE SP. A	0.2	0.2	0.4	.	.	.	.	.	.	0.8	0.8	0.4	0.8	0.8	0.8
65	GLUCINDE SOLITARIA	.	.	.	0.2	0.2	0.2	0.4	0.2	0.2	0.6	0.6	0.4	0.4	0.4	0.4
65	NEREIS SP.	.	.	.	.	.	.	.	.	.	1.0	1.0	0.3	0.4	0.4	0.4
71	SCHISTOMERINOS RUDOLPHI	0.4	0.4	0.4	0.2	0.2	0.2	0.4	0.4	0.4	0.6	0.6	0.2	0.2	0.2	0.2
71	LATHELETES PARVULUS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
71	NEOPANOPE SAYI	0.4	0.4	0.4	0.2	0.2	0.2	0.4	0.4	0.4	0.6	0.6	0.2	0.2	0.2	0.2
71	UXYURCSTYLIS SMITHI	1.4	0.5	0.5	.	.	.	.	.	.	.	.	.	0.2	0.2	0.2
71	MULINIA LATERALIS	1.0	0.5	0.4	.	.	.	.	.	.	0.4	0.4	0.4	0.4	0.4	0.4
71	MAGELONA SP. A	1.0	0.5	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
71	SINATULIDA TENTACULATA	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4
71	ACETES AMERICANUS	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4
71	PROTHESIS ATLANTICA	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4
71	LISIMIELLA BARNARDI	.	.	.	.	.	.	.	.	.	1.0	1.0	0.5	1.2	1.2	1.2
71	TIRON THOPAKIS	.	.	.	.	.	.	.	.	.	1.0	1.0	0.6	1.0	1.0	1.0
71	ASTYRIS LUNATA	0.2	0.2	0.2	.	.	.	0.2	0.2	0.2	0.8	0.8	0.4	0.8	0.8	0.8
71	PELECYPODA B	0.2	0.2	0.2	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4
71	PELECYPODA S	0.2	0.2	0.2	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2	1.0	1.0	1.0
71	UNUPHIDAE	0.2	0.2	0.2	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2	0.8	0.8	0.8
71	CISTENIDES GOULDII	0.8	0.4	0.4	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4
71	EXOSONE DISPAR	0.2	0.2	0.2	0.6	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
71	SQUILLA EMPUSA	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
71	HUMANTIELLA SP.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
71	SYNAPTIDAE A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
71	ASPIDOSIPHON ALBUS	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
71	PRIONOSPION FALLAX	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
71	SPIONIDAE	0.6	0.2	0.2	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
71	PARAONIDAE	.	.	.	.	.	.	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
71	HRANIA CLAVATA	.	.	.	.	.	.	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
71	NOTOCIRRUS SPINIFERUS	.	.	.	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4
71	ELASMOPIUS LEVIS	0.4	0.4	0.4	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
71	COROPHIUM SP.	0.2	0.2	0.2	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
71	ATYLLUS SP.	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
71	PARYLLICINA MULTILINEATA	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2	.	.	.	0.6	0.6	0.6
71	MACHIA FRAGILIS	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.6	0.6	.	.	.	0.6	0.6	0.6
71	AECCA AEGUALIS	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4	0.2	0.2	0.2
71	PLEURCHMERIS TRIDENTATA	.	.	.	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.6	0.6	0.2	0.2	0.2
71	SIPUNCULIDA SP.	.	.	.	0.8	0.5	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
71	PRIONOSPION SP.	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4
71	GLYCERA SP. B	0.2	0.2	0.2	.	.	.	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2
71	SPIOCAETOPTERUS COSTARUM OCULATUS	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4
71	URILONERIS MAGNA	0.2	0.2	0.2	.	.	.	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.2	0.2
71	MAGELONA PHYLLISAE	0.2	0.2	0.2	.	.	.	0.6	0.6	0.6	0.4	0.4	0.4	0.2	0.2	0.2
71	CAULLERIELLA KILLARIENSIS	0.2	0.2	0.2	.	.	.	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.2	0.2
71	AMPHARETE AMERICANA	.	.	.	0.4	0.4	0.4	.	.	.	0.6	0.6	0.6	0.4	0.4	0.4
71	OLSSOGACTYLUS MELLITAE	.	.	.	0.4	0.4	0.4	.	.	.	0.4	0.4	0.4	0.2	0.2	0.2
71	UPONEBIA SP.	.	.	.	.	.	.	.	.	.	0.4	0.4	0.4	0.2	0.2	0.2
71	XANTHIDAE	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
71	PROLONA POLITA	0.6	0.4	0.4	0.6	0.4	0.4	.	.	.	.	.	.	.	.	.
71	ANCINUS DEPRESSUS	0.4	0.4	0.4	0.2	0.2	0.2	.	.	.	.	.	.	.	.	.
71	BOMANIELLA BRASILIENSIS	0.2	0.2	0.2	0.2	0.2	0.2	0.6	0.6	0.6	0.6	0.6	0.6	0.2	0.2	0.2
71	ERVILLIA CONCENTRICA	0.4	0.4	0.4	.	.	.	.	.	.	.	.	.	.	.	.
71	PARVANACHIS UHESA	0.4	0.4	0.4	0.2	0.2	0.2	.	.	.	0.4	0.4	0.4	0.2	0.2	0.2
71	PELECYPODA	0.4	0.4	0.4	0.2	0.2	0.2	.	.	.	0.4	0.4	0.4	0.2	0.2	0.2
71	MAGELONA SP. A	0.2	0.2	0.2	0.2	0.2	0.2	.	.	.	0.4	0.4	0.4	0.2	0.2	0.2
71	ANGUSTROSYLLIS SP.	.	.	.	.	.	.	.	.	.	0.4	0.4	0.4	0.4	0.4	0.4
71	HOUEA ENIGMATICA	.	.	.	.	.	.	.	.	.	0.6	0.6	0.6	0.6	0.6	0.6
71	ONUPHIS REGULOSA	.	.	.	0.2	0.2	0.2	.	.	.	0.4	0.4	0.4	0.2	0.2	0.2
71	NEPHYS INCISA	.	.	.	.	.	.	0.2	0.2	0.2	0.4	0.4	0.4	0.2	0.2	0.2
71	POLYDORA SP.	.	.	.	.	.	.	.	.	.	0.4	0.4	0.4	0.2	0.2	0.2

## CONTROL AREA, SUMMER SAMPLES

RANK	SPECIES	CS02			CS05			CS09			CS11			CS13		
		MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR
117	PHYLLCOCIDAE	0.2	0.2											0.2	0.2	0.2
117	POLYNIDAE	0.2	0.2											0.2	0.2	
142	OSACHILA TUREMOSA				0.2	0.2								0.2	0.2	
142	PENAEIDAE							0.2	0.2							
142	OSTHACODA															0.2
142	ACANTHOMASTORIUS MILLSI															0.2
142	ACANTHOPURA MAGNIFICA				0.4	0.4								0.4	0.2	
142	MICROPOTOPUS SP.				0.4	0.2								0.4	0.4	
142	EPICANTHUS AMERICANUS				0.2	0.2										
142	HELICITA UGUESPERFORATA															
142	HELIOTOPUS															
142	HEMICHOERATA A	0.2	0.2					0.2	0.2							
142	HEMICHOERATA G															
142	INVERTERATA U															
142	HELLINA TEXANA				0.4	0.2								0.4	0.2	0.2
142	SPISULA SOLIDISSIMA													0.4	0.2	0.2
142	TURRONILLA SP. B													0.4	0.2	0.2
142	TURRONILLA SP. C													0.4	0.4	
142	MELANELLA SP.															
142	EPISCYNIA MULTICARINATA															
142	OPHELIA MULTICULATA				0.4	0.4								0.2	0.2	0.2
142	POLYDORA TETRABRANCHIA													0.4	0.4	0.4
142	PALAEONOSULLIS SP.															
142	UNYLLLEYDIA	0.2	0.2													
142	GLYCERA AMERICANA															
142	UPHINIA AMERICANA	0.4	0.2		0.4	0.4										
142	NEREIS LAMELLOSA	0.2	0.2		0.2	0.2								0.2	0.2	0.2
142	ARMANCIA MACULATA	0.2	0.2		0.2	0.2								0.2	0.2	0.2
142	HEMIGONETIDAE B															
142	AMPHARETIDAE															
142	PRIONOSPION CHISTATA															
142	MAGELGNA ROSEA	0.2	0.2											0.2	0.2	0.2
142	SIGAMBRA BASSI													0.4	0.2	0.2
142	SPIO SETUSA													0.2	0.2	0.2
195	BRANCHIUSTOMA CARIBAEUM															
195	PERILIMNES LONGICAUDATUS															
195	ALPHEUS CORPOSUS															
195	ALPHEUS POLICARIS	0.2	0.2													
195	PAGURUS SPINIMANUS															
195	MICROPHYPHYS PICORNUTUS															
195	HYPEROCRYPTA GRANULATA															
195	BRACHYURA B	0.2	0.2											0.2	0.2	0.2
195	PAGURIDAE															
195	PROCESSA HEMPHILLI															
195	SYNCHELIOTUM AMERICANUM				0.2	0.2		0.2	0.2							
195	RHEPOXYNIUS EPISTOMUS															
195	LYSIANOPSIS ALBA															
195	MICROPOTOPUS RANEYI				0.2	0.2		0.2	0.2					0.2	0.2	0.2
195	MICROPOTOPUS IRPEX															
195	BOBOLITHIDAE D															
195	PHOTIS PUGNATOR															
195	LEUCON AMERICANUS	0.2	0.2													
195	UNCIOLA SP.	0.2	0.2													
195	BOWMANIELLA FLORIDANA															
195	COMPHIITIDAE															
195	MICROPOTOPUS SPUMAKERI				0.2	0.2		0.2	0.2							
195	AMPHILOCHUS SP. A															
195	TURBELLARIA															
195	HEMIPHOLIS ELONGATA															
195	SCLEHODACTYLIA BRIAREUS															
195	OLIVETIDIA PYRAMIDATA															
195	OLIVELLA MUTICA															
195	NATICA PUSILLA															



Appendix 7. Overall ranked abundance of macroinvertebrates collected during winter at the disposal site. Mean density (number per 0.1 m<sup>2</sup>) and standard error of the mean at each station is indicated.

DISPOSAL AREA, WINTER SAMPLES																
RANK	SPECIES	DS03			US06			DS09			US11			CS13		
		MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR
1.0	ENSIS DIRECTUS	4.2	2.2	31.8	4.1	8.1	5.5	119.4	31.0	50.8	6.6	6.6				
2.0	CRASSINELLA MARTINICENSIS	15.0	2.5	15.6	15.1	15.6	6.9	0.2	0.2	41.4	7.7	7.7				
3.0	PLEURICHERIS TRIDENTATA	3.8	1.5	0.8	6.1	6.1	0.8	0.2	0.2	1.4	0.7	0.7				
4.0	SABELLARIA VULGARIS	0.4	0.2	14.4	1.3	14.4	14.4	0.2	0.2	8.2	3.5	3.5				
5.0	PHYDA VITTATA	3.0	1.1	0.8	3.6	3.6	0.8	0.2	0.2	4.0	1.6	1.6				
6.0	CPASSINELLA LUNULATA	0.4	0.8	3.0	0.6	3.0	1.0	0.2	0.2	5.2	2.3	2.3				
7.0	ACANTHOPHOSIUS MILLSI	0.3	0.3	7.0	0.6	7.0	3.9	0.2	0.2	7.2	2.6	2.6				
8.0	NEMATOCDA	1.0	0.5	1.8	0.4	1.8	0.7	0.8	0.6	2.0	1.3	1.3				
9.0	POLYCHORDILLOE A	1.4	0.2	2.4	0.2	2.4	0.9	3.0	0.8	2.4	0.6	0.6				
10.0	ASPIDOSIPHON GOSNOLDI	1.2	0.2	0.8	0.4	0.4	0.5	4.2	0.4	2.0	0.4	0.4				
11.0	NEPHETINEA	1.8	1.1	0.8	0.4	0.4	0.7	0.4	0.4	0.2	0.2	0.2				
12.0	METAPHRIA FLURIDANA	0.2	0.2	1.2	0.2	1.2	0.5	1.0	0.3	1.0	0.4	0.4				
13.0	OPHELIA DENTICULATA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
14.0	EUDEROPUS MONDURANUS	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
15.0	TRAVESIA PARVA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
16.0	PELECYPODA E	1.8	1.1	0.8	0.4	0.4	0.7	0.4	0.4	0.2	0.2	0.2				
17.0	AMPHIRODIA PULCHRELLA	0.2	0.2	0.8	0.4	0.4	0.5	1.0	0.3	1.0	0.4	0.4				
18.0	OXYURCISTYLIS SMITHI	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
19.0	SPIOPHANES COMBYX	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
20.0	LEPTOGNATHA CAECA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
21.0	MELITTIA QUIQUESPERFORATA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
22.0	MELITHONIS BRASILIENSIS	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
23.0	OLIGOCHAETA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
24.0	HATHYFOREIA PARKERI	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
25.0	POLYCIRRUS EXIMIUS	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
26.0	ACANTHOPHOSIUS INTERMEDIUS	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
27.0	NATICA PUSILLA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
28.0	PETRICOLA PHCLADIFORMIS	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2				
29.0	IPAVISTIA SP. A	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
30.0	NEPHYS PICTA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
31.0	HEMIPODUS ROSELS	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
32.0	SYNCHELIDIUM AMERICANUM	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
33.0	UMPHIS EREMITA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
34.0	HYANCHTOSTOMA CARIBAEUM	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
35.0	CYATHOLIRA RUBRANCKI	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
36.0	OPHIUROIDEA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
37.0	ECHINOIDEA A	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
38.0	PELECYPODA A	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
39.0	TELLINA SP. CEPHALA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
40.0	GLYCERIA OXYCERURA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
41.0	UNCERKE SERATA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
42.0	ONCICOLA SP.	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
43.0	ACTINIARIA SP.	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
44.0	SABELLARIA SP.	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
45.0	SCOLELEPIS SGUAMATA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
46.0	SPIO PETTIGNEAE	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
47.0	MALDANIAE	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
48.0	POLYDORA CAECA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
49.0	LOPHINERDES ACUTA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
50.0	APANTHURA MAGNIFICA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
51.0	LEMBOS SP.	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
52.0	NERVILLIA CONCENTRICA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
53.0	NUCULA PROXIMA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
54.0	PELECYPODA E	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
55.0	AMASTIGOS CAPERATUS	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
56.0	SPHAGROSYLIS ACICULATA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
57.0	LUMBERINUS LATREILLI	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
58.0	NEPHYS INCISA	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
59.0	GLYCERIDAE	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
60.0	MAGNOCNA PACIFICORNIS	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				
61.0	MELICOMASTUS CALIFORNENSIS	0.2	0.2	1.0	0.2	1.0	0.5	0.8	0.2	0.2	0.2	0.2				



[illegible]



## DISPOSAL AREA - SUMMER SAMPLES

RANK	SPECIES	US03			DS06			DS08			DS10			DS13		
		MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR
1	CUPULADRIA COMA	.	.	.	12.6	2.7	1	2.4	0.6	9	31.2	2.2	3	177.8	28.8	8
2	CRASSINELLA MARTINICENSIS	.	.	.	62.0	7.4	7	5.2	1.6	1.6	11.2	2.0	2	110.2	17.2	6
3	HYDRA VITATA	23.4	11.8	0.4	16.0	4.7	4	3.2	0.5	0.5	20.4	4.0	7	143.2	5.6	4
4	PARALLANIA VULGARIS	0.6	.	.	1.2	0.5	0	2.0	0.2	0.2	19.0	4.2	0	1.4	1.0	0
5	CRASSINELLA LUNCLATA	.	.	.	0.6	0.2	0	6.0	0.6	0.6	19.0	4.2	0	19.4	1.2	2
6	ASPIDOSTIPHON GOSNOLDI	.	.	.	17.2	3.5	3	0.6	0.4	0.4	0.2	0.2	0	0.6	4.8	3
7	PLEURONCHIS THICENTATA	0.4	0.5	0.5	1.4	0.5	0	5.2	1.1	1.1	3.4	1.8	1	5.8	3.8	9
8	ULIGONAEIA	1.2	0.4	0.4	0.2	0.2	0	0.6	0.4	0.4	7.4	4.5	4	13.4	1.5	5
9	ULISCOFORELLA UMBELLATA	0.4	0.2	0.2	1.0	0.8	0	3.4	1.0	1.0	1.4	1.4	1	5.6	1.5	5
10	MEGISTOMASTUS CALIFORNIENSIS	1.6	0.6	0.6	1.0	0.3	0	1.2	0.2	0.2	4.0	2.1	2	3.4	2.6	8
11	ENIS DIRECTUS	3.0	1.0	1.0	0.8	0.4	0	1.0	0.3	0.3	2.8	1.6	1	1.6	0.8	0
12	HEMATHONA	.	.	.	0.8	0.4	0	1.8	1.0	1.0	3.8	1.6	1	1.0	0.3	3
13	METHANOTRICHIA	.	.	.	0.6	0.2	0	0.6	0.2	0.2	3.4	1.0	1	3.6	2.2	2
14	POLYCHOTA FLORIDANA	.	.	.	0.4	0.2	0	0.6	0.2	0.2	4.0	1.6	1	1.4	0.7	4
15	CONIODES CAMLINAE	.	.	.	0.4	0.2	0	0.6	0.2	0.2	4.0	1.6	1	1.4	0.7	4
16	CIRROPHORUS LYTHIFORMIS	.	.	.	0.6	0.2	0	0.6	0.2	0.2	4.0	1.6	1	1.4	0.7	4
17	ANCISTROSYLLIS PARTMANAE	.	.	.	4.4	1.3	1	3.0	1.3	1.3	0.4	0.5	0	1.2	0.5	5
18	PAGURUS HENDERSONI	3.4	0.9	0.9	0.8	0.5	0	0.2	0.6	0.6	0.4	0.2	0	0.4	0.2	0
19	ACANTHOHAUSTORIUS MILLSI	0.4	0.2	0.2	0.8	0.4	0	1.8	1.0	1.0	0.4	0.4	0	0.6	0.4	2
20	HEMIPICUS ROSEUS	0.2	0.2	0.2	1.4	0.7	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
21	AMPHICOLA PULCHELLA	1.0	0.8	0.8	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
22	HOWMANIELLA SP.	0.6	0.2	0.2	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
23	KATPA CATHARTENSIS	1.0	0.8	0.8	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
24	RUDEVEGUS MONDURANUS	0.6	0.2	0.2	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
25	ANCINUS DEPRESSUS	0.2	0.2	0.2	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
26	GLYCERA DIBRANCHIATA	0.2	0.2	0.2	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
27	AUTOPATE EVERMANNI	0.6	0.2	0.2	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
28	COROPHUM SP. C	0.2	0.2	0.2	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
29	EVILLIA CONCENTRICA	0.6	0.2	0.2	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
30	ASPIDOSTIPHON ALPUS	0.2	0.2	0.2	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
31	SPIOPHANES BOMBYX	0.6	0.2	0.2	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
32	GYRURCTYLIS SMITHI	0.2	0.2	0.2	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
33	CYATHOGA HUBBARDI	0.2	0.2	0.2	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
34	PRIONOSPILIO FALLAX	0.2	0.2	0.2	0.4	0.4	0	1.8	1.0	1.0	1.6	0.4	0	0.6	0.4	2
35	PARATONOSPILUS SP. A	0.4	0.4	0.4	0.2	0.2	0	1.6	0.5	0.5	0.8	0.4	0	0.8	0.8	8
36	NEPTIS PICTA	0.4	0.4	0.4	0.2	0.2	0	1.6	0.5	0.5	0.8	0.4	0	0.8	0.8	8
37	TIRON TRIOCCELLATUS	0.4	0.4	0.4	0.2	0.2	0	1.6	0.5	0.5	0.8	0.4	0	0.8	0.8	8
38	PSEUDOURYTHOE AMBIGUA	0.2	0.2	0.2	0.2	0.2	0	2.2	1.5	1.5	0.2	0.2	0	0.4	0.4	2
39	EULALIA SANGUINEA	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
40	TRACHYPENAEUS CONSTRICTUS	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
41	OMENIA FUSIFORMIS	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
42	MYSICOPSIS RIGELOWI	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
43	ARRA AEGUALIS	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
44	PINNIXA RETIENS	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
45	POLYGORILLIDAE	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
46	GLYCERA OXYCEPHALA	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
47	HRANCHOSTOMA CARIBAEUM	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
48	LEPTOCHELA SEMIATROBITA	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
49	MELLITA QUINQUESPERFORATA	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
50	PARVILUCINA MULTILINEATA	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
51	UPRINIA AMERICANA	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
52	SIGAMBRA BASSI	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
53	PINNIXA SP.	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
54	LEPTONATHA CAECA	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
55	HOWMANIELLA BRASILIENSIS	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
56	TELLINIA PROPRINA	0.2	0.2	0.2	0.2	0.2	0	0.6	0.4	0.4	0.8	0.5	0	0.4	0.4	2
57	PELECEPHALUS SP. A	0.4	0.4	0.4	0.4	0.4	0	0.4	0.4	0.4	0.4	0.4	0	0.2	0.2	0
58	GLYCERINUS ACUTA	0.4	0.4	0.4	0.4	0.4	0	0.4	0.4	0.4	0.4	0.4	0	0.2	0.2	0
59	LUMBRINERIS ATLANTICA	0.2	0.2	0.2	0.4	0.2	0	0.2	0.2	0.2	0.2	0.2	0	0.2	0.2	0
60	ACTINARIA	0.2	0.2	0.2	0.4	0.2	0	0.2	0.2	0.2	0.2	0.2	0	0.2	0.2	0

## DISPOSAL AREA, SUMMER SAMPLES

RANK	SPECIES	DS03			DS06			DS08			DS10			DS13		
		MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR
67	SPISULA SOLICISSIMA	0.4		0.4	0.4		0.2	0.6		0.4	0.4		0.4		0.2	0.2
67	MACRIS FRAGILIS							0.4		0.4			0.6			
65	PELICYPODA															
65	UPHELIA DENTICULATA				0.8		0.2			0.2		0.6		0.2		0.2
65	PARAPETIOPUS PINNATA							0.2		0.2		0.6		0.4		
65	ARCHARETE AMERICANA	0.2		0.2				0.8		0.4						
65	PHOTCHAUSTORIUS DEICHMANNAE				0.6		0.2			0.2					0.2	0.2
77	ERICHTHONIUS BRASILIENSIS														0.2	0.2
77	ACANTHONIAUS HORIUS SHOENAKERI														0.4	0.6
77	SPIDUPHANES SP. A															
77	PILARGIDAE										0.8		0.6			
77	POLYCHAETUS EXIMIUS							0.2		0.4		0.4		0.2		0.2
77	SPITOCHEIROPTERUS COSTALUM OCELLATUS				0.2		0.2	0.2		0.2		0.2		0.2		0.2
77	DRILLONEREIS MAGNA				0.2		0.2	0.2		0.2		0.4		0.4		0.4
77	PARAONIDAE										0.2		0.6		0.2	0.2
77	SPID PETITHCNEAE							0.2		0.2		0.4		0.2		0.2
77	CAULLEHIELLA KILLARIENSIS	0.2		0.2			0.4	0.2		0.2		0.4		0.4		0.4
77	MALDANIDAE				0.6						0.4		0.4		0.4	0.4
77	SCISTOCYRINUS RUDOLPHI										0.2		0.2		0.2	0.2
77	SCISTOCYRINUS CIRRIFERA							0.2		0.2		0.2		0.2		0.2
77	SCHISTOMYXINUS CAECA				0.4		0.6									
92	PINNIXIA CHAETOPTERANA				0.6											
92	HETEROCRYPTA GRANULATA															
92	CHOLANA POLITA															
92	UNCIONA SERPENS															
92	TIRON TROPAKIS															
92	HEMICHOORDATA A							0.6		0.4		0.2		0.2		0.2
92	INVERTEBRATA U							0.2		0.4		0.2		0.2		0.2
92	CORHULA BARHATTIANA				0.4		0.2									
92	POLYCHAETA A				0.6		0.2									
92	UNUPHIS SP				0.2		0.2									
92	THAIXIA MARIONI				0.4		0.2									
92	ARICIDEA SUECICA				0.4		0.2									
92	ABABELLA MUTANS															
92	NEREIS SUCCINEA															
92	NEREIS SP.															
116	UPOGEBIA AFFINIS							0.4		0.2		0.4		0.4		0.2
116	EUCERAMUS PHAELONGUS							0.2		0.2		0.2		0.2		0.2
116	PAGURUS LONGICARPUS							0.2		0.2		0.2		0.2		0.2
116	OVALIPES STEPHENSONI	0.2		0.2				0.2		0.2		0.2		0.2		0.2
116	UPOGEBIA SP.															
116	HYACHTYRA							0.4		0.2		0.2		0.2		0.2
116	MICHOFOPODUS HANEYI							0.4		0.2						
116	CEGAMUS RUBICARIS	0.2		0.2				0.2		0.2						
116	CEOTEA MONTOSA	0.4		0.4												
116	COROPPIUM SP.															
116	BOWMANIELLA FLORIDANA				0.2		0.2	0.2		0.2						0.2
116	TURBELLARIA							0.2		0.2						0.2
116	CUCUMARIA PULCHERPIMA															0.2
116	GLOTTIDIA PYRAMIDATA															0.2
116	NUCULA PROXIMA															0.2
116	LYONSIA HYALINA	0.4		0.2				0.2		0.2						0.2
116	TURRONILLA SP. H							0.4		0.4						0.4
116	MAGELCMA SF							0.4		0.4						0.4
116	SEBELLARIIDAE															0.4
116	MELODORVILLEA SP. A															0.4
116	HYALOMENIA SP. A				0.2		0.2									0.2
116	SCOLOPUS RUERA															0.2
116	GLYCERA SP.															0.2
116	GLYCERA CAPITATA															0.2
116	LISTENIDES GOULCII				0.4		0.4									0.4

AD-A153 478

BENTHIC AND SEDIMENTOLOGICAL STUDIES OF THE GEORGETOWN  
OCEAN DREDGED MATE. (U) SOUTH CAROLINA WILDLIFE AND  
MARINE RESOURCES DEPT CHARLESTON S.C.

2/2

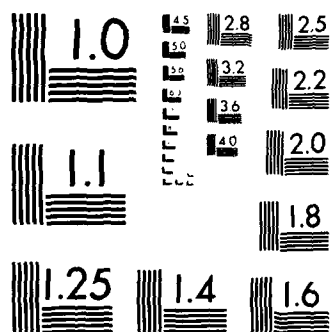
UNCLASSIFIED

R F VAN DOLAH ET AL. FEB 84 TR-59

F/G 8/18

NL





MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS 1963-A

Appendix 8. (Continued)

RANK	SPECIES	DS03				DS06				DS08				DS10				DS13			
		MEAN	ST	ERR		MEAN	ST	ERR		MEAN	ST	ERR		MEAN	ST	ERR		MEAN	ST	ERR	
116	SYNLEPIS ALPINE	.	.	.	.	0.4	0.4	.	.	.	0.2	0.2	.	.	0.2	0.2	.	0.4	0.4	.	.
116	CAPITATA	.	.	.	.	0.2	0.2	.	.	0.2	0.2	.	.	0.2	0.2	.	.	.	.	.	.
116	EXOGONE	.	.	.	.	0.2	0.2	.	.	0.2	0.2	.	.	0.2	0.2	.	.	.	.	.	.
116	THARYX SP.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.4	0.4	.	.	.	.	.	.
116	MACROSCOPUS FRAGILIS	.	.	.	.	0.2	0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
116	ARMANDIA MACULATA	0.2	0.2	.	.	0.2	0.2	.	.	.	.	.	.	.	.	.	.	0.4	0.4	.	.
116	HEXAGONIDAE	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
116	LIMNATULIDAE	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	LATREUTES ALPHAEOSTRIS	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	.	.	.	.
165	USACHILA TURBOSA	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	.	.	.	.
165	PORTUNUS GIBBESII	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	.	.	.	.
165	PROCESSA AMPHILLI	0.2	0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	SQUILLA EMPUSA	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	.	.	.	.
165	SYNCHELIDIUM AMERICANUM	.	.	.	.	0.2	0.2	.	.	0.2	0.2	.	.	.	.	.	.	.	.	.	.
165	HATHYDREIA PARKERI	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
165	LEMBOS UNICORNIS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
165	ACANTHOHAUSTORIUS INTERMEDIUS	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	PHOTIS PUGNATOR	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
165	MYSTICACEA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	APANTHURA MAGNIFICA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	ANOPLODACTYLUS PETIOLATUS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	OPHIUROIDEA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	PHOLYDORIDEA	0.2	0.2	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.	0.2	0.2	.	.
165	CURLYADRIIDEA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	TELLINAE	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	MACROINAE	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	CREPICULA SP.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	OSTREA EQUETHIS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	CHAMA MACROPHYLLA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	LIMA PELLUCIDA	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	PELECYPODA S.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	MULINIA LATERALIS	0.2	0.2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	TURRONILLA SP. D	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.
165	TEREBRA LONCATA	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	TELLINIDAE	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	AMELANA TRILOBATA	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	SYLLIS GRACILIS	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	MAGELCNA SP. D	.	.	.	.	0.2	0.2	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	AUTOLYTUS SP. D	.	.	.	.	0.2	0.2	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	PRIONOSPION SP. A	.	.	.	.	0.2	0.2	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	OPHELIDAE	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	NERETS FALSA	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	SPHAEROSYLLIS ACICULATA	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	UNIPHIDAE	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	LUMPHINIS LATREILLI	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	PISTIA CRISTATA	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	CLIPACORUS BRANCHIATUS	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	ARICIDEA CERRUTI	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	DIPTICUNCINATA	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	SCOLELEPIS SQUAMATA	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	PHYLLODOCE MUCOSA	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	ARABELLA IRICOLCR	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	LEPIDONOTUS SUBLEVIS	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	PODARKE OHSCURA	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	MAGELONA PAPILLICORNIS	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	POECLIOCHAEUS SP.	.	.	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	SPIONIDAE	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.	.	.	.	.	0.2	0.2	.	.
165	SPIONIDAE A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0.2	0.2	.	.

Appendix 8. (Continued)

RANK	SPECIES	DISPOSAL AREA, SUMMER SAMPLES											
		DS03			DS06			DS08			DS10		
		MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR
165	URBINIIDAE	.	.	.	.	.	.	0.2	0.2	.	0.2	0.2	.
165	THAUYA ANNULOSUS	.	.	.	.	.	.	0.2	0.2	.	0.2	0.2	.
165	POLYDORA SP. B	.	.	.	.	.	.	0.2	0.2	.	0.2	0.2	.
165	POLYDORA SP. G	.	.	.	.	.	.	.	.	.	0.2	0.2	.
165	GONIACIDAE	.	.	.	.	.	.	.	.	.	0.2	0.2	.
165	BRANIA CLAVATA	.	.	.	.	.	.	.	.	.	0.2	0.2	.
165	PHYLLGDOCE ARENAE	.	.	.	.	.	.	.	.	.	0.2	0.2	.
165	POLYDORA CAECA	.	.	.	.	.	.	0.2	0.2	.	.	.	0.2
165	PRIONOSPION CHENSATA	.	.	.	.	.	.	.	.	.	.	.	.
165	SIGALION AENEICOLA	.	.	.	.	.	.	.	.	.	.	.	.
165	THAUYA PARVA	.	.	.	0.2	0.2	.	.	.	.	0.2	0.2	.

Appendix 9. Overall ranked abundance of macroinvertebrates collected during winter at the "down current" site. Mean density (number per 0.1 m<sup>2</sup>) and standard error of the mean at each station is indicated.

## DOWN CURRENT AREA, WINTER SAMPLES

RANK	SPECIES	DC01		DC02		DC03	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
1	ENSIS DITEGIUS	112.4	25.2	28.4	4.8	6.8	0.8
2	POLYCHORDIDAE A	25.4	16.4	1.4	0.4	1.0	0.8
3	NEMATELIDA	11.2	1.5	0.2	0.2	1.0	0.8
4	POLYCHORDIDAE B	3.4	0.2	3.4	0.7	0.4	0.2
5	POLYCHORDIDAE C	1.6	0.4	1.4	0.7	0.4	0.2
6	POLYCHORDIDAE D	2.0	0.5	1.2	0.7	1.6	0.8
7	POLYCHORDIDAE E	0.4	0.2	1.4	0.4	0.2	0.2
8	POLYCHORDIDAE F	1.0	0.5	0.6	0.4	0.2	0.2
9	POLYCHORDIDAE G	1.2	1.2	1.2	0.7	0.2	0.2
10	POLYCHORDIDAE H	0.8	0.4	0.4	0.2	0.2	0.2
11	POLYCHORDIDAE I	0.2	0.2	0.4	0.2	0.2	0.2
12	POLYCHORDIDAE J	1.0	0.5	1.0	0.6	0.2	0.2
13	POLYCHORDIDAE K	1.2	0.6	0.6	0.4	0.2	0.2
14	POLYCHORDIDAE L	0.6	0.4	0.4	0.4	0.2	0.2
15	POLYCHORDIDAE M	0.2	0.2	0.2	0.2	0.2	0.2
16	POLYCHORDIDAE N	0.4	0.4	0.4	0.4	0.2	0.2
17	POLYCHORDIDAE O	0.4	0.4	0.4	0.4	0.2	0.2
18	POLYCHORDIDAE P	0.4	0.4	0.4	0.4	0.2	0.2
19	POLYCHORDIDAE Q	0.4	0.4	0.4	0.4	0.2	0.2
20	POLYCHORDIDAE R	0.4	0.4	0.4	0.4	0.2	0.2
21	POLYCHORDIDAE S	0.4	0.4	0.4	0.4	0.2	0.2
22	POLYCHORDIDAE T	0.4	0.4	0.4	0.4	0.2	0.2
23	POLYCHORDIDAE U	0.4	0.4	0.4	0.4	0.2	0.2
24	POLYCHORDIDAE V	0.4	0.4	0.4	0.4	0.2	0.2
25	POLYCHORDIDAE W	0.4	0.4	0.4	0.4	0.2	0.2
26	POLYCHORDIDAE X	0.4	0.4	0.4	0.4	0.2	0.2
27	POLYCHORDIDAE Y	0.4	0.4	0.4	0.4	0.2	0.2
28	POLYCHORDIDAE Z	0.4	0.4	0.4	0.4	0.2	0.2
29	POLYCHORDIDAE AA	0.4	0.4	0.4	0.4	0.2	0.2
30	POLYCHORDIDAE AB	0.4	0.4	0.4	0.4	0.2	0.2
31	POLYCHORDIDAE AC	0.4	0.4	0.4	0.4	0.2	0.2
32	POLYCHORDIDAE AD	0.4	0.4	0.4	0.4	0.2	0.2
33	POLYCHORDIDAE AE	0.4	0.4	0.4	0.4	0.2	0.2
34	POLYCHORDIDAE AF	0.4	0.4	0.4	0.4	0.2	0.2
35	POLYCHORDIDAE AG	0.4	0.4	0.4	0.4	0.2	0.2
36	POLYCHORDIDAE AH	0.4	0.4	0.4	0.4	0.2	0.2
37	POLYCHORDIDAE AI	0.4	0.4	0.4	0.4	0.2	0.2
38	POLYCHORDIDAE AJ	0.4	0.4	0.4	0.4	0.2	0.2
39	POLYCHORDIDAE AK	0.4	0.4	0.4	0.4	0.2	0.2
40	POLYCHORDIDAE AL	0.4	0.4	0.4	0.4	0.2	0.2
41	POLYCHORDIDAE AM	0.4	0.4	0.4	0.4	0.2	0.2
42	POLYCHORDIDAE AN	0.4	0.4	0.4	0.4	0.2	0.2
43	POLYCHORDIDAE AO	0.4	0.4	0.4	0.4	0.2	0.2
44	POLYCHORDIDAE AP	0.4	0.4	0.4	0.4	0.2	0.2
45	POLYCHORDIDAE AQ	0.4	0.4	0.4	0.4	0.2	0.2
46	POLYCHORDIDAE AR	0.4	0.4	0.4	0.4	0.2	0.2
47	POLYCHORDIDAE AS	0.4	0.4	0.4	0.4	0.2	0.2
48	POLYCHORDIDAE AT	0.4	0.4	0.4	0.4	0.2	0.2
49	POLYCHORDIDAE AU	0.4	0.4	0.4	0.4	0.2	0.2
50	POLYCHORDIDAE AV	0.4	0.4	0.4	0.4	0.2	0.2
51	POLYCHORDIDAE AW	0.4	0.4	0.4	0.4	0.2	0.2
52	POLYCHORDIDAE AX	0.4	0.4	0.4	0.4	0.2	0.2
53	POLYCHORDIDAE AY	0.4	0.4	0.4	0.4	0.2	0.2
54	POLYCHORDIDAE AZ	0.4	0.4	0.4	0.4	0.2	0.2
55	POLYCHORDIDAE BA	0.4	0.4	0.4	0.4	0.2	0.2
56	POLYCHORDIDAE BB	0.4	0.4	0.4	0.4	0.2	0.2
57	POLYCHORDIDAE BC	0.4	0.4	0.4	0.4	0.2	0.2
58	POLYCHORDIDAE BD	0.4	0.4	0.4	0.4	0.2	0.2
59	POLYCHORDIDAE BE	0.4	0.4	0.4	0.4	0.2	0.2
60	POLYCHORDIDAE BF	0.4	0.4	0.4	0.4	0.2	0.2
61	POLYCHORDIDAE BG	0.4	0.4	0.4	0.4	0.2	0.2
62	POLYCHORDIDAE BH	0.4	0.4	0.4	0.4	0.2	0.2
63	POLYCHORDIDAE BI	0.4	0.4	0.4	0.4	0.2	0.2
64	POLYCHORDIDAE BJ	0.4	0.4	0.4	0.4	0.2	0.2
65	POLYCHORDIDAE BK	0.4	0.4	0.4	0.4	0.2	0.2
66	POLYCHORDIDAE BL	0.4	0.4	0.4	0.4	0.2	0.2
67	POLYCHORDIDAE BM	0.4	0.4	0.4	0.4	0.2	0.2
68	POLYCHORDIDAE BN	0.4	0.4	0.4	0.4	0.2	0.2
69	POLYCHORDIDAE BO	0.4	0.4	0.4	0.4	0.2	0.2
70	POLYCHORDIDAE BP	0.4	0.4	0.4	0.4	0.2	0.2
71	POLYCHORDIDAE BQ	0.4	0.4	0.4	0.4	0.2	0.2
72	POLYCHORDIDAE BR	0.4	0.4	0.4	0.4	0.2	0.2
73	POLYCHORDIDAE BS	0.4	0.4	0.4	0.4	0.2	0.2
74	POLYCHORDIDAE BT	0.4	0.4	0.4	0.4	0.2	0.2
75	POLYCHORDIDAE BU	0.4	0.4	0.4	0.4	0.2	0.2
76	POLYCHORDIDAE BV	0.4	0.4	0.4	0.4	0.2	0.2
77	POLYCHORDIDAE BW	0.4	0.4	0.4	0.4	0.2	0.2
78	POLYCHORDIDAE BX	0.4	0.4	0.4	0.4	0.2	0.2
79	POLYCHORDIDAE BY	0.4	0.4	0.4	0.4	0.2	0.2
80	POLYCHORDIDAE BZ	0.4	0.4	0.4	0.4	0.2	0.2
81	POLYCHORDIDAE CA	0.4	0.4	0.4	0.4	0.2	0.2
82	POLYCHORDIDAE CB	0.4	0.4	0.4	0.4	0.2	0.2
83	POLYCHORDIDAE CC	0.4	0.4	0.4	0.4	0.2	0.2
84	POLYCHORDIDAE CD	0.4	0.4	0.4	0.4	0.2	0.2
85	POLYCHORDIDAE CE	0.4	0.4	0.4	0.4	0.2	0.2
86	POLYCHORDIDAE CF	0.4	0.4	0.4	0.4	0.2	0.2
87	POLYCHORDIDAE CG	0.4	0.4	0.4	0.4	0.2	0.2
88	POLYCHORDIDAE CH	0.4	0.4	0.4	0.4	0.2	0.2
89	POLYCHORDIDAE CI	0.4	0.4	0.4	0.4	0.2	0.2
90	POLYCHORDIDAE CJ	0.4	0.4	0.4	0.4	0.2	0.2
91	POLYCHORDIDAE CK	0.4	0.4	0.4	0.4	0.2	0.2
92	POLYCHORDIDAE CL	0.4	0.4	0.4	0.4	0.2	0.2
93	POLYCHORDIDAE CM	0.4	0.4	0.4	0.4	0.2	0.2
94	POLYCHORDIDAE CN	0.4	0.4	0.4	0.4	0.2	0.2
95	POLYCHORDIDAE CO	0.4	0.4	0.4	0.4	0.2	0.2
96	POLYCHORDIDAE CP	0.4	0.4	0.4	0.4	0.2	0.2
97	POLYCHORDIDAE CQ	0.4	0.4	0.4	0.4	0.2	0.2
98	POLYCHORDIDAE CR	0.4	0.4	0.4	0.4	0.2	0.2
99	POLYCHORDIDAE CS	0.4	0.4	0.4	0.4	0.2	0.2
100	POLYCHORDIDAE CT	0.4	0.4	0.4	0.4	0.2	0.2

Appendix 9. (Continued)

RANK	SPECIES	DOWN CURRENT AREA, WINTER SAMPLES								
		DC01			DC02			DC03		
		MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR
57	STREPTOSYLLIS SP.	0.2		0.2	0.2		0.2	.	.	.
57	PSEUDOCURYTHOE AMBIGUA	0.2		0.2	0.2		0.2	.	.	.
57	NEPHTYS INCISA	0.2		0.2	0.2		0.2	.	.	.
57	ANCISTROSYLLIS MARTMANAE	0.2		0.2	.		.	.	.	.
57	SCOLCPELOS SP.	0.2		0.2	.		.	.	.	.
57	GLYCERIDAE	.		.	.		.	0.2	0.2	0.2
57	UNUPHIS EHEMITA	.		.	0.2		0.2	.	.	.
57	PODARKE OHSCURA	.		.	0.2		0.2	.	.	.
57	CAPITELLIDAE	0.2		0.2	0.2		0.2	.	.	.
57	GONIACIDAE	.		.	0.2		0.2	.	.	.
57	POLYDORA CAECA	.		.	0.2		0.2	0.2	0.2	0.2
57	NEPHTYIDAE	.		.	.		.	.	.	.



Appendix 10. Overall ranked abundance of macroinvertebrates collected during summer at the "down current" site. Mean density (number per 0.1 m<sup>2</sup>) and standard error of the mean at each station is indicated.

## DOWN CURRENT AREA, SUMMER SAMPLES

MARK	SPECIES	UC01			UC02			UC03		
		MEAN	ST	ERR	MEAN	ST	ERR	MEAN	ST	ERR
1	CUPULADRIA UDMA	0.2		0.2	49.2		8.6			
2	ENSIS UMECTUS	12.0		3.3	0.4		0.4			
3	LYURA VITTATA	1.0		0.4	10.4		2.1			0.3
4	PARAPRIONOSPILUS PINNATA	0.2		0.2						0.2
5	CRASSINELLA PARTINICENSIS	4.2		0.8	0.6		0.4			
6	MAGELONAE PHYLISAE	5.0		1.2						
7	ULIGOCMAETA VULGARIS				4.6		1.2			0.4
8	SABELLARIA PICTA	9.4		0.2	2.4		0.4			
9	NEPHTYS PICTA	3.0		0.5	0.8		0.4			1.4
10	NEPHELETHES				0.8		0.6			
11	HATEA CATHARTINENSIS									2.1
12	MULINIA LATENS	0.2		0.2	0.2		0.2			1.5
13	PAGURUS HENRICSONI	0.2		0.2	2.2		0.9			0.4
14	MEDIOASTUS CALIFORNIENSIS	0.2		0.2	0.2		0.2			1.1
15	ANCINUS DEPRESSUS	0.2		0.2	2.4		0.6			
16	HEMIPRUS ROSEI	0.4		0.4						1.6
17	CERAPUS TUBULARIS	0.2		0.2	1.8		0.6			
18	SPIDOPANES ROMBYX	0.2		0.2						
19	MAGELONAE SP. A	1.8		0.5						
20	PLEURONCHIS IMIDENTATA	0.2		0.2	1.4		0.6			
21	AMPHIODIA PULCHRELLA	0.2		0.2			1.2			
22	HEMICORDATA A				0.2		0.2			0.7
23	POLYCORDIDAE A	1.2		0.4						
24	ANCISTROSYLLIS HARTMANAE				1.4		0.9			
25	AMPHARETE AMERICANA									1.4
26	PAGURUS LONGICARPUS									0.6
27	MELITA QUINGUESPERFORATA									
28	CERPIDULA PLANA	0.8		0.5						
29	ACTINOTRACHEA	0.4		0.4						
30	ACTINOTRACHEA EVERMANNI	0.4		0.4						
31	ACTINOTRACHEA EVERMANNI	0.4		0.4						
32	ACTINOTRACHEA EVERMANNI	0.4		0.4						
33	ACTINOTRACHEA EVERMANNI	0.4		0.4						
34	ACTINOTRACHEA EVERMANNI	0.4		0.4						
35	ACTINOTRACHEA EVERMANNI	0.4		0.4						
36	ACTINOTRACHEA EVERMANNI	0.4		0.4						
37	ACTINOTRACHEA EVERMANNI	0.4		0.4						
38	ACTINOTRACHEA EVERMANNI	0.4		0.4						
39	ACTINOTRACHEA EVERMANNI	0.4		0.4						
40	ACTINOTRACHEA EVERMANNI	0.4		0.4						
41	ACTINOTRACHEA EVERMANNI	0.4		0.4						
42	ACTINOTRACHEA EVERMANNI	0.4		0.4						
43	ACTINOTRACHEA EVERMANNI	0.4		0.4						
44	ACTINOTRACHEA EVERMANNI	0.4		0.4						
45	ACTINOTRACHEA EVERMANNI	0.4		0.4						
46	ACTINOTRACHEA EVERMANNI	0.4		0.4						
47	ACTINOTRACHEA EVERMANNI	0.4		0.4						
48	ACTINOTRACHEA EVERMANNI	0.4		0.4						
49	ACTINOTRACHEA EVERMANNI	0.4		0.4						
50	ACTINOTRACHEA EVERMANNI	0.4		0.4						
51	ACTINOTRACHEA EVERMANNI	0.4		0.4						
52	ACTINOTRACHEA EVERMANNI	0.4		0.4						
53	ACTINOTRACHEA EVERMANNI	0.4		0.4						
54	ACTINOTRACHEA EVERMANNI	0.4		0.4						
55	ACTINOTRACHEA EVERMANNI	0.4		0.4						
56	ACTINOTRACHEA EVERMANNI	0.4		0.4						
57	ACTINOTRACHEA EVERMANNI	0.4		0.4						
58	ACTINOTRACHEA EVERMANNI	0.4		0.4						
59	ACTINOTRACHEA EVERMANNI	0.4		0.4						
60	ACTINOTRACHEA EVERMANNI	0.4		0.4						
61	ACTINOTRACHEA EVERMANNI	0.4		0.4						
62	ACTINOTRACHEA EVERMANNI	0.4		0.4						
63	ACTINOTRACHEA EVERMANNI	0.4		0.4						
64	ACTINOTRACHEA EVERMANNI	0.4		0.4						
65	ACTINOTRACHEA EVERMANNI	0.4		0.4						
66	ACTINOTRACHEA EVERMANNI	0.4		0.4						
67	ACTINOTRACHEA EVERMANNI	0.4		0.4						
68	ACTINOTRACHEA EVERMANNI	0.4		0.4						
69	ACTINOTRACHEA EVERMANNI	0.4		0.4						
70	ACTINOTRACHEA EVERMANNI	0.4		0.4						
71	ACTINOTRACHEA EVERMANNI	0.4		0.4						
72	ACTINOTRACHEA EVERMANNI	0.4		0.4						
73	ACTINOTRACHEA EVERMANNI	0.4		0.4						
74	ACTINOTRACHEA EVERMANNI	0.4		0.4						
75	ACTINOTRACHEA EVERMANNI	0.4		0.4						
76	ACTINOTRACHEA EVERMANNI	0.4		0.4						
77	ACTINOTRACHEA EVERMANNI	0.4		0.4						
78	ACTINOTRACHEA EVERMANNI	0.4		0.4						
79	ACTINOTRACHEA EVERMANNI	0.4		0.4						
80	ACTINOTRACHEA EVERMANNI	0.4		0.4						
81	ACTINOTRACHEA EVERMANNI	0.4		0.4						
82	ACTINOTRACHEA EVERMANNI	0.4		0.4						
83	ACTINOTRACHEA EVERMANNI	0.4		0.4						
84	ACTINOTRACHEA EVERMANNI	0.4		0.4						
85	ACTINOTRACHEA EVERMANNI	0.4		0.4						
86	ACTINOTRACHEA EVERMANNI	0.4		0.4						
87	ACTINOTRACHEA EVERMANNI	0.4		0.4						
88	ACTINOTRACHEA EVERMANNI	0.4		0.4						
89	ACTINOTRACHEA EVERMANNI	0.4		0.4						
90	ACTINOTRACHEA EVERMANNI	0.4		0.4						
91	ACTINOTRACHEA EVERMANNI	0.4		0.4						
92	ACTINOTRACHEA EVERMANNI	0.4		0.4						
93	ACTINOTRACHEA EVERMANNI	0.4		0.4						
94	ACTINOTRACHEA EVERMANNI	0.4		0.4						
95	ACTINOTRACHEA EVERMANNI	0.4		0.4						
96	ACTINOTRACHEA EVERMANNI	0.4		0.4						
97	ACTINOTRACHEA EVERMANNI	0.4		0.4						
98	ACTINOTRACHEA EVERMANNI	0.4		0.4						
99	ACTINOTRACHEA EVERMANNI	0.4		0.4						
100	ACTINOTRACHEA EVERMANNI	0.4		0.4						

RANK	SPECIES	DOWN CURRENT AREA, SUMMER SAMPLES					
		DC01		UC02		DC03	
		MEAN	ST ERR	MEAN	ST ERR	MEAN	ST ERR
63	EUDEVENOPUS HONCHUANUS						
63	PELECYPODA	0.2	0.2	0.4	0.2	.	.
63	CREPICULA FORNICATA	.	.	0.2	0.2	.	.
63	SCOLOPLOS RUHRA	0.4	0.2	0.4	0.4	.	.
63	AGLAOPHAGMUS VERRILLI	0.4	0.2	.	0.2	.	.
63	DISPIO UNCINATA	0.4	0.2	.	.	.	.
63	SIGAMERA TENTACULATA	0.4	0.2	.	.	.	.
63	TRAVISIA SP. C	.	.	0.4	0.4	.	.
63	GLYCIDAE SOLITARIA	.	.	.	0.4	.	.
63	DIOPATRA CUPHEA	0.4	0.2	0.2	0.2	0.4	0.2
63	MAGELONA PAPILLICORNIS	.	.	0.4	0.2	0.2	.
63	SPIO PETIIBONEAE	.	.	0.2	0.2	.	.
63	FRANCHOTOMA CARIBAEUM	.	.	.	0.2	.	.
97	LEPTOCHELA SEMRATORBITA	.	.	.	.	.	.
97	LATHEUTES PARVULUS	.	.	.	.	.	.
97	PORTUNUS SAYANA	.	.	.	.	.	.
97	PENAEIDAE GIBBESII	.	.	.	0.2	0.2	0.2
97	PINNOTHERES SP.	.	.	.	.	0.2	0.2
97	ALPHEUS SP.	0.2	0.2	.	.	.	.
97	RHEPOXYNIUS EPISTOMUS	0.2	0.2	.	.	0.2	0.2
97	ACANTHOHAUSTORIUS INTERMEDIUS	.	.	0.2	0.2	.	.
97	MYSTACIDAE	0.2	0.2	.	.	0.2	0.2
97	HOMMANIELLA SP.	.	.	.	.	.	.
97	MICROPROTOPUS SHOEMAKERI	0.2	0.2	0.2	0.2	.	.
97	MICROPROTOPUS SP.	.	.	0.2	0.2	.	.
97	ROMANIELLA BRASILIENSIS	.	.	0.2	0.2	.	.
97	TRIGUN TRICELLATUS	.	.	.	0.2	.	.
97	OLIVELLA PUSILLA	0.2	0.2	0.2	0.2	.	.
97	NATICA PUSILLA	0.2	0.2	0.2	0.2	.	.
97	TELLINA PROBRINA	.	.	0.2	0.2	.	.
97	ARMA AEGUALIS	0.2	0.2	0.2	0.2	.	.
97	TEREBRA CONCAVA	.	.	0.2	0.2	.	.
97	TEREBRA DYSLOCATA	.	.	0.2	0.2	.	.
97	ECHEURIDA	.	.	.	0.2	.	.
97	ONUPHIS SP. A	.	.	.	0.2	.	.
97	ONUPHIS SP. A	.	.	.	0.2	.	.
97	ACROCIERIDAE A	0.2	0.2	0.2	0.2	.	.
97	GLYCIDAE	0.2	0.2	0.2	0.2	.	.
97	LUMBRINERIS LATILLI	0.2	0.2	0.2	0.2	.	.
97	POLYDORA COMPENSALIS	0.2	0.2	0.2	0.2	.	.
97	PHRETS SUCINEA	0.2	0.2	0.2	0.2	.	.
97	ONUPHIS EREMITA	.	.	.	0.2	.	.
97	PUDARKE OHSCURA	.	.	.	0.2	.	.
97	POLYDORA LIGNI	.	.	.	0.2	.	.
97	POECILOCHAETUS SP.	.	.	.	0.2	.	.
97	NESTONIDAE	.	.	.	0.2	.	.
97	THALYX ANNULOSUS	.	.	.	0.2	.	.
97	MALDANIDAE SP.	0.2	0.2	0.2	0.2	.	.
97	POLYDORA	.	.	.	.	.	.
97	SYLLIDAE	.	.	.	.	.	.
97	CLAVATA	.	.	.	0.2	.	.
97	MANIA SANGUINEA	.	.	.	0.2	.	.
97	EULALIA CAECA	.	.	.	0.2	.	.
97	POLYDORA SP. B	.	.	.	0.2	.	.
97	TRAVISIA SP. B	.	.	.	0.2	.	.
97	CHISTOMERIDAE CAECA	.	.	.	0.2	.	.
97	LUMBRINERIDES ACUTA	.	.	.	0.2	.	.

Appendix 11. Species diversity and faunal density of grab samples collected in the study area. The units for values of H' are bits.

STATION	DIVERSITY (H')	EVENNESS (J')	RICHNESS (SR)	NUMBER OF INDIVIDUALS/0.5 m <sup>2</sup>	NUMBER OF SPECIES
WINTER					
CS02	3.8	0.6	11.2	832	76
CS04	4.7	0.7	12.0	794	81
CS09	5.0	0.8	13.4	559	86
CS10	5.6	0.7	23.9	3120	193
CS13	4.5	0.7	15.7	1252	113
DS03	3.4	0.7	6.3	192	34
DS06	3.2	0.6	6.8	472	43
DS09	4.2	0.7	12.0	571	77
DS11	1.4	0.3	5.0	736	34
DS13	3.4	0.6	10.3	741	69
DC01	2.0	0.4	5.3	851	37
DC02	3.4	0.6	8.3	282	48
DC03	3.2	0.7	4.6	78	21
SUMMER					
CS02	3.9	0.6	10.5	500	66
CS05	4.3	0.7	11.1	426	68
CS09	4.9	0.8	12.5	371	75
CS11	5.8	0.8	19.3	754	129
CS13	5.2	0.7	17.5	1410	128
DS03	3.0	0.6	6.7	219	37
DS06	3.4	0.6	10.6	721	71
DS08	5.8	0.9	16.8	454	104
DS10	4.6	0.7	12.8	778	86
DS13	3.1	0.5	12.9	2171	100
DC01	4.3	0.8	9.3	234	52
DC02	3.7	0.6	12.2	518	77
DC03	3.7	0.8	5.3	166	28

Appendix 12. Tissue sample analysis of *Busyon carica* from Georgetown DMDS area.  
(CH - channel, CS - control, DS - disposal, DC - down current)

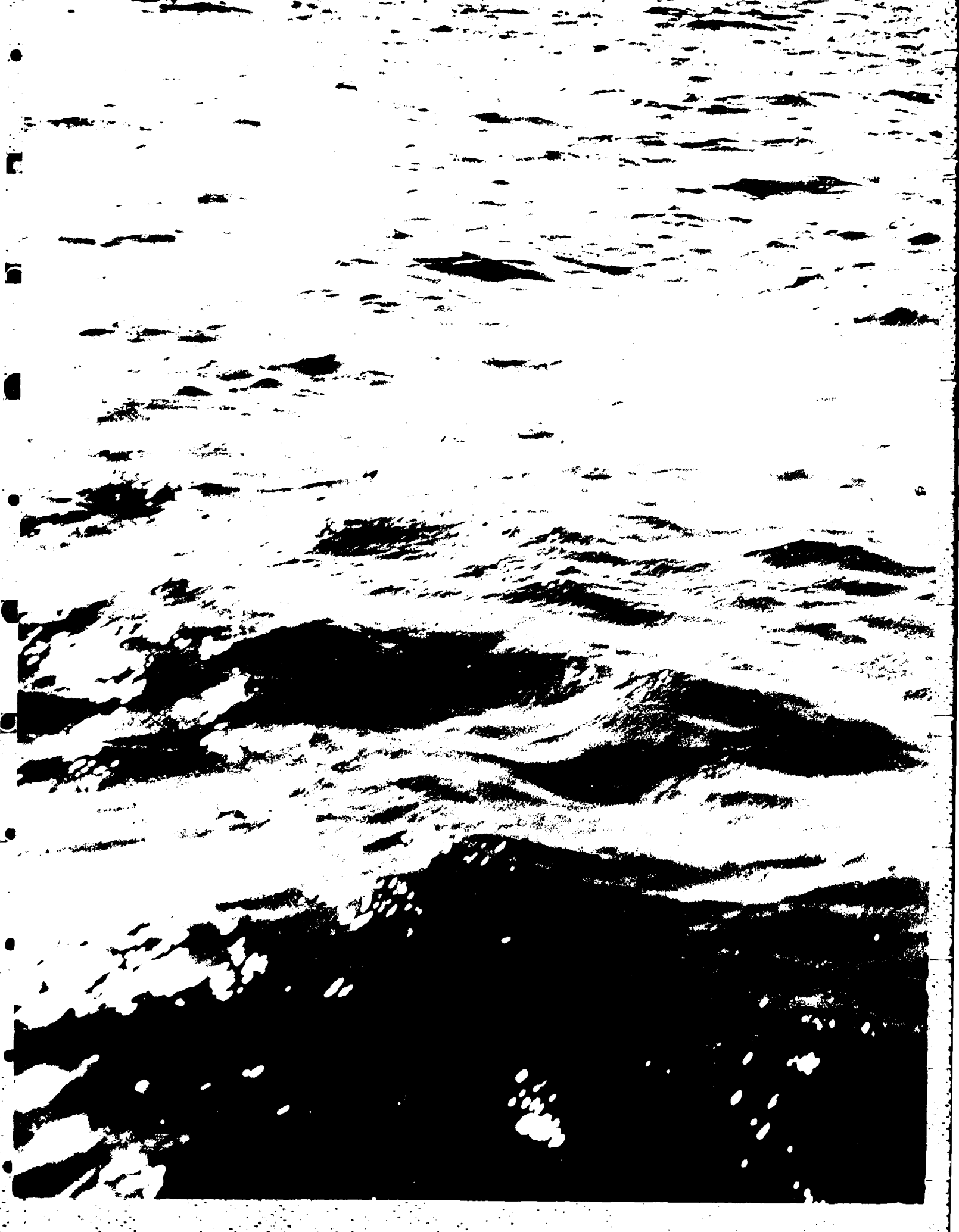
	CS		DS		DC		SPIKE CS		SPIKE DC	
PCBs $\mu\text{g/g}$	ND		ND		ND		1254 PCB -			
-BHC $\mu\text{g/g}$	ND		ND		ND		100.0%			
lindane $\mu\text{g/g}$	ND		ND		ND		59.8%			
heptachlor $\mu\text{g/g}$	ND		ND		ND					
B-BHC $\mu\text{g/g}$	ND		ND		ND					
aldrin $\mu\text{g/g}$	ND		ND		ND					
heptachlor epoxide $\mu\text{g/g}$	ND		ND		ND					
P, P' - DDE $\mu\text{g/g}$	ND		ND		ND					
O, P' - DDD $\mu\text{g/g}$	ND		ND		ND					
O, P' - DDT $\mu\text{g/g}$	ND		ND		ND					
chlordane $\mu\text{g/g}$	ND		ND		ND					
dieldrin $\mu\text{g/g}$	ND		ND		ND					
endrin $\mu\text{g/g}$	ND		ND		ND		100.0%			
P, P' - DDD $\mu\text{g/g}$	ND		ND		ND					
P, P' - DDT $\mu\text{g/g}$	ND		ND		ND					
mirex $\mu\text{g/g}$	ND		ND		ND					
methoxychlor $\mu\text{g/g}$	ND		ND		ND					
toxaphene $\mu\text{g/g}$	ND		ND		ND		134.9%			
Wet wt. of sample extracted $\mu\text{g/g}$	50.6597		51.8103		50.8697					
Total resolved Hydrocarbons by GC $\mu\text{g/g}$	ND		ND		ND					
Total Unresolved Hydrocarbons by GC $\mu\text{g/g}$	ND		ND		ND					
Sum of the n-Alkanes $\mu\text{g/g}$	ND		ND		ND					

C18 58.3% Recovery  
C19 48.7% Recovery  
C20 53.1% Recovery  
C22 41.7% Recovery

Appendix 12. (Continued)

	<u>CS</u>	<u>DS</u>	<u>DC</u>
Sum of the even n-Alkanes $\mu\text{g/g}$	ND	ND	ND
Sum of the odd n-Alkanes $\mu\text{g/g}$	ND	ND	ND
Unresolved Hydrocarbons/Resolved Hydrocarbons $\mu\text{g/g}$	ND	ND	ND
Pristane + Phytane/n-Alkanes $\mu\text{g/g}$	ND	ND	ND
Odd n-Alkanes/Even n-Alkanes $\mu\text{g/g}$	ND	ND	ND
Pristane/n-17 $\mu\text{g/g}$	ND	ND	ND
Phytane/n-18 $\mu\text{g/g}$	ND	ND	ND
Pristane/Phytane $\mu\text{g/g}$	ND	ND	ND
n-Alkanes/Branched Hydrocarbons $\mu\text{g/g}$	ND	ND	ND
Cadmium $\mu\text{g/g}$	< 0.1	< 0.1	< 0.1
Arsenic $\mu\text{g/g}$	1.67	2.34	1.92
Chromium $\mu\text{g/g}$	< 0.1	< 0.1	< 0.1
Nickel $\mu\text{g/g}$	< 0.5	< 0.5	< 0.5
Copper $\mu\text{g/g}$	6.15	9.65	7.09
Lead $\mu\text{g/g}$	< 0.5	< 0.5	< 0.5
Mercury $\mu\text{g/kg}$	< 1.0	< 1.0	< 1.0
Zinc $\mu\text{g/g}$	52.28	53.61	50.77

ND - Not Detected; Detection Limit is 50 ppb.



**END**

**FILMED**

**6-85**

**DTIC**